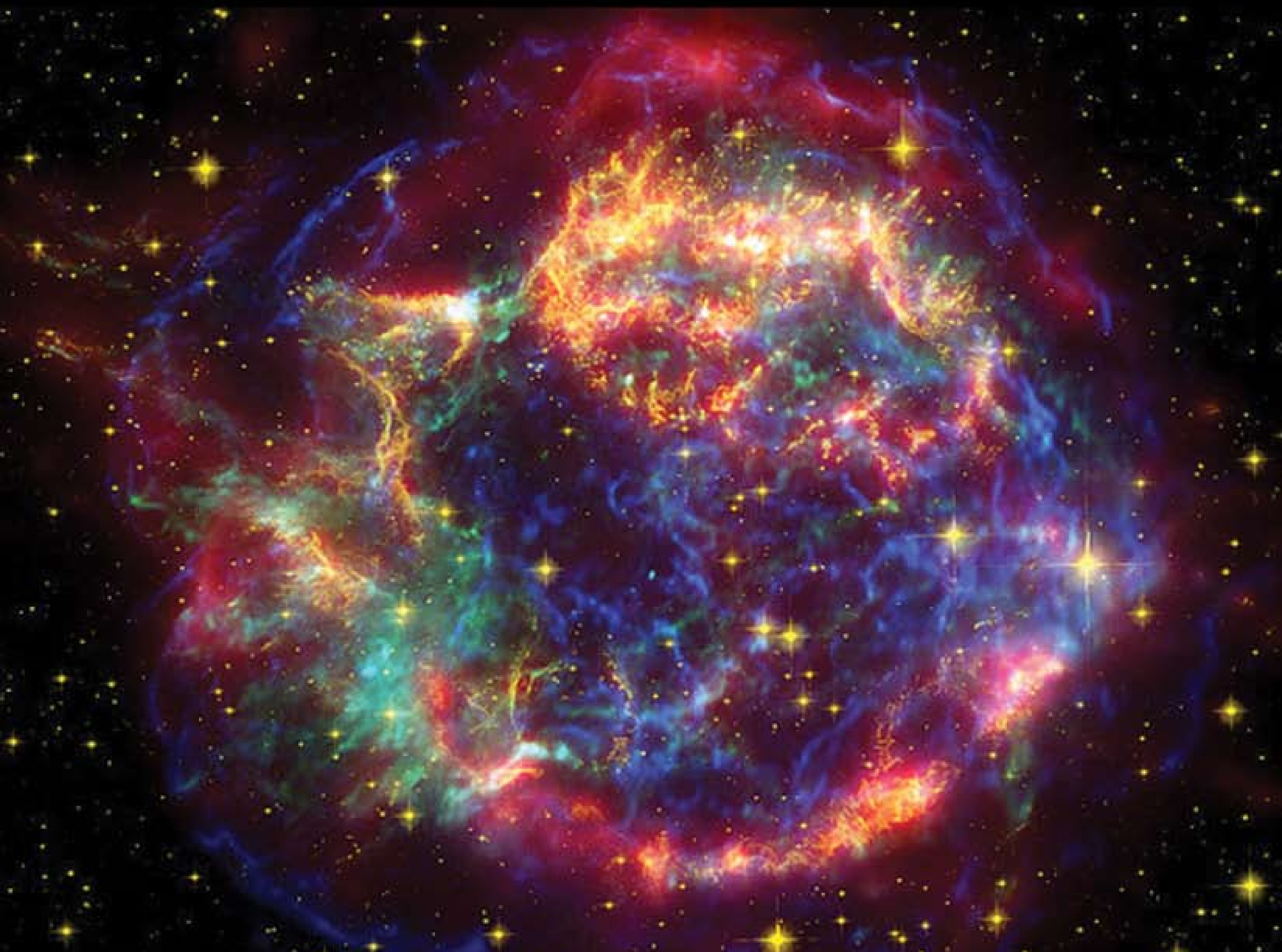
Big Explosions and Strong Gravity



Bringing Black Holes to Girls: A Manual for Running the Program

Fall 2010 Version

Introduction

Big Explosions and Strong Gravity is a one day Girl Scout event during which girls earn a patch for the back of their sash or vest, and have the opportunity to learn about astronomy firsthand from actual scientists and engineers. Although all the activities are gender-neutral, we have focused on girls because of their underrepresentation in science and because we have a fruitful partnership with a local Girl Scout council. We target the middle school age range because there is a general decline in interest in math and science that occurs at or after children reach this critical age. It is our hope that this program will help to retain and reengage students' interest in math and science.

During this event, girls explore the abundance of elements in the universe, spectroscopy, supernovae, and black holes in four sessions that run approximately 45-60 minutes each. Whenever possible, these sessions are led by professional astronomers, engineers, and graduate students in related fields; however, we recognize that in most places there are not enough local scientists available to make this practical. In these cases, we strongly encourage prospective organizers to involve at least a few such people and have them interact with the students so that this aspect of the program is not lost. Even if insufficient numbers of scientists and engineers are available in your area for them to lead all the classrooms, it is possible to achieve all of the benefits of this program with only a few people.

This program has been run five times over the years 2004-2010 with the Girl Scouts of Central Maryland with great success. Thanks to a NASA ROSES grant, we have been working to expand the program nationwide with the goal of making it available to any council who would like to run it. As of this version of the manual, two other councils have also run the program and a number of other councils have been trained to do so.

This manual has been developed to assist in making this program available nationwide and to make it easier for people who are less familiar with the activities and content to organize the program and run the sessions. Although the sessions are listed in a certain order within this manual, there is no set progression that the students must follow. The first two activities provide a good basis for the last two, but within those pairings they can be done in any order. More explanation of this is included in the section on how to run the program.

This program was originally developed in the Johns Hopkins University Department of Physics and Astronomy, with participation from members of NASA Goddard Space Flight Center and the Space Telescope Science Institute, as well as the Girl Scouts of Central Maryland. It is currently administered by Dr. Ann Hornschemeier and Ms. Sarah Eyermann, both of NASA Goddard Space Flight Center.

Please visit our website at http://bigexplosions.gsfc.nasa.gov/ for more information. If you have any questions, please email bigexplosions-qa@majordomo.gsfc.nasa.gov. We always appreciate feedback and suggestions.

Contributors

We wish to recognize the contributions of the following scientists who have contributed significant time to the development of the BESG activities and this manual.

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We also wish to acknowledge the above-and-beyond administrative help of Ms. Sheryl Falgout (JHU 2003-2004, now at NOAO) for her assistance in getting this program started.

Acknowledgements

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The success of this program has only been possible due to the assistance of many people and groups. We would specifically like to acknowledge the following:

- ★ Chandra X-ray Center for donating calendars, board games, bookmarks, postcards and other items
- ★ Johns Hopkins University Department of Physics and Astronomy and Catholic University of America for donating space for activities and storage
- ★ Girl Scouts of Central Maryland Girl Scout council for assisting us with the development and testing of this program

Table of Contents

Program Summary

Big Explosions and Strong Gravity is a one-day Girl Scout astronomy event in which girls in grades 5-7 or 8 participate in hands-on activities designed to give them a better understanding of the composition of the universe, the electromagnetic spectrum, supernovae, and black holes. The event includes four sessions of approximately 45-60 minutes each, and whenever possible, these sessions are led by astronomers, engineers, and graduate students in related fields. The sessions are as follows:

<u>Elements and You</u>
Students are introduced to the periodic table and the concept of elements. The group will discuss how all material in the universe is composed of elements and that the atom is the smallest particle that still has the physical and chemical properties of any given element. As an exercise in statistics, the students will participate in a counting experiment in which they sample a 'universe bead mix' (where each bead color represents a different element present in the universe) to estimate the overall composition of the universe. In the next activity, they compare their findings of the universe's overall composition with the composition of various different objects in the universe that are represented by mixtures of rice, beans and other dried goods in jars. Finally, the idea of fusion creating heavier elements from hydrogen inside a star is introduced.

<u>Rainbow Analysis</u>
Students are introduced to the electromagnetic spectrum and the scientific tool of spectroscopy. They will each build a simple spectroscope with which they can examine the light from different light sources, particularly the Sun (if logistically feasible) and artificial lights (fluorescent or sodium lamps, discharge lamps, or whatever is available locally). The solar spectrum will appear continuous at the resolution typical of plastic diffraction gratings; however, the fluorescent or sodium room lights and discharge lamps will show clear spectral lines (students often describe the spectra as "broken up"). These lines represent the "fingerprint" of the particular element contained in the lights and are always the same, no matter where the element appears or how much of the element is present. The appearance of a given fingerprint in the spectrum of a distant astronomical object demonstrates the presence of that substance in the object. The discharge lamps provide the opportunity to show students a variety of spectral fingerprints.

<u>Supernova Explosions</u>
Students are reminded that the universe is made up of elements and that the heavier elements are created inside of a star as they learned in the "Elements and You" activity. They are introduced to the life cycle of a star and to the way in which a star's mass affects its process of fusion and eventual death. The physical concept of equilibrium as a balancing of forces is discussed, and an experiment is conducted to demonstrate what happens to a soda can when the interior and exterior forces are not in equilibrium. An analogy is made between this experiment and core collapse in stars, to show the importance of maintaining equilibrium in stars. Finally, it is demonstrated how mass is ejected from a collapsed star in a supernova explosion, thereby dispersing heavier elements throughout the universe.

<u>Black Holes in Orbit</u>
Students are introduced to the basic properties, behavior and detection of black holes through a brief discussion of common conceptions of black holes and how black holes might be detected through their interaction with other objects. Then they "act out" this detection process by representing binary star systems in pairs, walking slowly around one another in a darkened room with each pair holding loops of wire to simulate the gravitational interaction. Most of the students are wearing glow-in-the-dark headbands to simulate stars, some are not wearing headbands to represent black holes, and a small set of the black holes have flashlights to simulate X-ray emission.

How to Run this Program

FIND A PARTNER

So you're a Girl Scout council and you think this would be wonderful for your girls to experience. Or you're a scientist and you want to help bring these activities to girls in your area. The first thing you need to do is to find a local partner. This program works best as a partnership between a Girl Scout council and space scientists. If you are a Girl Scout council, try talking to the physics department at universities in your area, as well as any science or engineering company. If you are a scientist, you can find out how to contact your local Girl Scout council through the Girl Scout website at http://www.girlscouts.org/councilfinder/.

FIND A LOCATION

Once you have a partner, you need a location. This event has been successfully run in a variety of settings, including Girl Scout facilities and universities.

Below are some space and other requirements to keep in mind when picking your location:

- At least four rooms total are necessary.
- At least one room should be big enough for everybody to gather is also necessary. There is some advantage to having this be a 5th room instead of one of the four, but this is not necessary.
- At least two of the rooms must be able to be completely darkened.
- The two "dark-ready" rooms also need space for people to move around without bumping into desks, etc.
- There must be additional space (whether in the other two non-dark rooms or a space outside or in a hallway, etc) for getting up, moving around and playing with balls without hurting anything/body when they bounce around.
- The rooms should not be too spread out so that people do not get lost going between them.
- Ideally, noise should not carry greatly between the rooms to avoid the different groups disturbing each other.
- There should be sufficient free parking available.
- Make sure that any necessary steps are taken with the security at your location to ensure that everybody can reach the location on that day (access to location, buildings locked, etc.) and that there will be no problems with security while you are there.

SET A DATE

You may need to set your date six months in advance, or even more, in order to get on calendars and the appropriate advertisement lists. There are several things you should keep in mind while setting a date.

- You will probably need a full day, so a Saturday is recommended.
- Make sure there are no other events going on in the Girl Scout council or at your location that will be serious competition for volunteers or attendance or that will get in your way at the location. Girl Scout staff can be very helpful with checking council calendars, and there will be a contact at your location that will have the calendar for that location as well.
- Avoid holidays that might be competition.

FIND VOLUNTEERS

You will need two types of volunteers: science-specific volunteers and more general volunteers that can be anybody, including scientists if you have enough of them. The more scientists you can get in the room with the girls, the better. The first several times we ran this program, our volunteer staff consisted almost entirely of scientists, but we recognize that this will be hard to replicate in most areas.

The scientist volunteers serve two functions for this event. First, they understand the background and can teach other volunteers what they need to know in order to successfully discuss the science side of these activities with the girls. Second, they provide an opportunity for the girls to meet real live scientists/engineers (hopefully including some female scientists/engineers), talk to them about what their career is like, and start to realize that scientists and engineers really are people too. The same scientists, or different ones, depending on schedules and availability, can easily serve these two functions.

When we have run this program, we have set an upper limit of 100 girls and then divided them into 4 groups of 25. We recommend staying within these limits. We also recommend at least 3 volunteers with each group of 25 girls, making the minimum number of volunteers you would need to be 12 (or twice that if your volunteers only work half days). It is helpful to have extras to take care of lunch and any necessary rearranging, etc, while the girls are still busy with activities.

TRAIN VOLUNTEERS

As mentioned above, you need to make sure that all of your volunteers are familiar with the science behind the different activities. This means it would be helpful to have a training session for volunteers without the necessary science background. Even if all your volunteers are subject matter experts, we still highly recommend practicing or rehearsing the activities and making sure that they are prepared for all questions. Presenting to middle-school aged children requires preparation, even for scientists.

When we have run this program we have had two activities in the morning, and two in the afternoon. For 100 girls, you should have at least 6 volunteers who understand each morning activity and 6 who understand each afternoon activity. This way you can have 2 parallel groups of 25 girls doing one activity while the other 2 groups do the other activity, and then they switch, in both the morning and afternoon sessions. If volunteers are staying all day, they can do both a morning and an afternoon activity. These numbers may change if you run this program with a different schedule/format than what we have used. Scheduling options are discussed later.

We suggest that for the training, the scientists run the activities with the general volunteers acting as the students. Scientists should emphasize the science explanations during the training, as that is most likely the part that volunteers with no science background will struggle with.

HANDOUTS AND "PRIZES"

We have always provided the girls with a folder of handouts in the morning when they first arrive. While this is not necessary, we think this adds a nice touch. You can get astronomy handouts from many different educational resource providers. A very easy and very appropriate option is NASA's Chandra X-ray Observatory program. They will happily provide free resources for an event such as this. Their request form can be found at http://chandra.harvard.edu/edu/request.html. Make sure you allow at least 3-4 weeks for the materials to reach you.

A periodic table is also useful to include in this folder of materials, particularly in the discussion in the Elements and You session. This folder also provides a useful place to include the schedule for the day, evaluation forms, and anything else the girls might need to read or fill out. Free periodic tables can be downloaded from a number of sites online, and options for where you can order large quantities of periodic tables are listed in Appendix B.

It can also be nice to have small little prizes (space stickers, bookmarks, postcards, posters, etc) to encourage girls' participation in discussion and to give as prizes for completion of certain activities, such as the scavenger hunt. Again, these are not necessary, but the girls love them.

In the past we have included t-shirts as part of this event, however they added significantly to the complexity and expense of the event. After conducting a survey about event costs, we learned that girls and parents do not consider this very important, and as a result we have decided to forgo them. You, however, are free to choose differently. We have a graphic available that does not have a specific date on it so that the leftover shirts are reusable for future events.

While we have determined t-shirts to be unnecessary, the Girl Scout patch is more important. Girl Scouts display this on their vest to show that they have completed an event or activity, and they will be disappointed if such is not available. In addition to a graphic for the patch, which we will happily share, we have a supply of these patches available for a limited time for councils who run the Big Explosions and Strong Gravity program. Check out the resources portion of our website for information on how to request these for your council.

LUNCH

Since this is an all-day event, it is important to make provisions for lunch, both for the girls and for the volunteers. It might be prudent to provide something simple in the morning for the volunteers as well, but this is up to your discretion.

SCHEDULE

Although the sessions are listed in a certain order within this manual, there is no set progression that the students must follow. We recommend that the first two activities be done first because they provide a good basis for the last two, but within these pairings they can be done in any order. Each session is designed as an individual recipe, and, therefore, could also be run independently of the others if you are looking for a single activity rather than a full-day event.

When we have run this program, we have had a target number of 100 participants. These we divide into four groups of 25 girls, in which they stay for the entire day. For the first session of the morning, two of the groups participate in Elements and You and the other two in Rainbow Analysis. After the first hour, they switch units so that those who just did the Elements and You unit now do Rainbow Analysis and vice versa.

After the morning activities, we frequently do an activity relating to black holes just before lunch. This activity has changed from year to year, and has included a quiz show designed by other Girl Scouts, a video about black holes, a black hole trivia maze, and others. During lunch we have included a scavenger hunt, the point of which is to let the girls interact with scientists/engineers to see that they are real people too. The questions relate to hobbies, family, history, and life in general, as well as questions about the scientist's work. You may edit these questions however you want, but an example we have used can be found in Appendix D.

In the afternoon, the girls again divide into their four groups. Two of the groups do the Supernova Explosions activity while the other two do the Black Holes in Orbit activity. After an hour, they switch in the same manner as before. An example of the schedule we have used for this event can be found in Appendix C.

SOME TIPS FOR THE DAY

At the beginning of each session after the first, ask the students what they just learned or what they have learned so far today. This will help them with retention of the knowledge they have gained as well as provide a bridge to the next activity in many cases.

Use volunteers from among the girls to pass out handouts, help demonstrate, etc. This helps to get them up and moving and also keeps them engaged.

PHOTO RELEASE

You may need a photo release from each girl's parents in order to use photos from these events, since these girls are minors. Many Girl Scout councils will have one of these on file for each girl, but you will need to check whether this will extend to any agency other than the council. We would love to receive photos of your event for inclusion on our website and in other places. In order for this to be possible, we need a copy of the NASA photo release form signed by a parent for each girl, in addition to any forms needed from your end.

Suggestions for Leading Middle School Aged Girl Scouts

While many scientists and engineers may be accomplished teachers in a university setting, they may not have experience interacting with middle school aged children. There are some key differences in how to successfully interact with this age group as opposed to adults or even high-school aged students. Below you will find some useful tips, as well as some specific points to consider when working with Girl Scouts.

1. Whenever possible, engage the students by encouraging their participation in the activities. Make it an interactive experience by asking them questions, involving them in demonstrations, etc.

2. Do NOT lecture. You will lose their interest almost immediately. If you feel the material calls for a lecture, see the previous point and try to involve the students as much as possible.

3. Get them up and moving around whenever there's an opportunity. Things as simple as calling a volunteer come up for a minute to demonstrate something or asking the group to get up occasionally, even if it's just to pick up a piece of paper and sit down again, will keep them more involved and therefore more engaged.

4. Girl Scout culture has an established method of quieting a noisy room that can be used to your advantage. Raising the right hand over the head to signal for attention is known as the quiet sign. The key part of this is that when someone holds their hand in the air in this manner, no one is allowed to speak. THIS INCLUDES THE PRESENTER, so do not hold your hand up and continue speaking. As each person in the room sees this, they too will hold their hand in the air until the entire room has caught on. Once the entire room is silent and all hands are in the air, you may lower your hand and speak to the group. In some areas you may see the Girl Scout sign (3 fingers up, as pictured to the right), used in this manner instead of just a hand in the air.

5. Girl Scouts frequently come with parents who will attend such events with the girls. This can be very useful in maintaining order among the girls, and you should feel free to use parents for that purpose. The downside of having adults present is that girls may feel more intimidated, and the adults can feel the need to jump in with answers if the girls are shy or uncertain, or if they are taking a while to come up with a response to a general question. You should gently discourage this as the activities are designed for the girls' benefit rather than their parents. It is sometimes helpful to have alternate activities for adults to be engaged in rather than mixing with the girls.

6. Girl Scouts frequently want to know what badge requirements they might be able to complete as they do activities, so you should be forewarned that such questions might come up. Whether you choose to address these questions or discourage them entirely is up to you. In the future we will try to include a resource on the webpage that addresses these questions in relation to these activities, but it will certainly not be an exhaustive list.

Elements and You

Summary

Students are introduced to the periodic table and the concept of elements. The group discusses how all material in the universe is composed of elements, and discusses the atom as the smallest particle that still has the physical and chemical properties of a given element. As an exercise in statistics, the students participate in a counting experiment in which they sample a 'universe bead mix' (where each bead color represents a different element present in the universe) to estimate the overall composition of the universe. In the next activity, they compare the universe's overall composition with the compositions of various different objects in the universe, using bottles filled with mixtures of rice, beans, and other dried goods to represent the different elements. Finally, students are introduced to the idea that elements heavier than hydrogen are created inside a star in the process called fusion.

Objectives

- ★ To understand what an element is
- ★ To become familiar with a periodic table and common elements
- ★ To determine the most abundant elements in the universe
- ★ To learn how heavier elements form from fusion
- ★ To gain knowledge of the processes in the interior of a star
- ★ To explore the concept of composition in the context of astronomical objects
- ★ To explore how elements link us to stars

Materials

- ★ Plain pound cake *
- ★ Knife to cut the pound cake
- ★ Gloves or wet wipes for safe food handling
- ★ Napkins or paper plates to hold the pound cake (enough to serve the group, if allowed)
- ★ Example(s) of pure elements (sheet of aluminum, copper tubing, elemental density cubes, etc.) **
- ★ Large display copy of a periodic table **
- ★ Periodic table handouts for each student (both color and black and white examples can be found following this session)
- ★ Large bowl to mix the bead mix
- ★ Multi-colored pony beads (or other beads of the same size and weight; see preparatory procedure for colors and amounts)
- ★ Small scoops or Dixie cups
- ★ Handouts or transparency of Universe of Beads key ***
- ★ Universe of Beads worksheets
- ★ Bottle activity ingredients (see preparatory procedures for amounts): white and brown rice, split peas, black beans, white beans, pinto beans, red beans, red lentils, and brown lentils ****
- ★ 8 oz plastic bottles with lids

- ★ Funnel for pouring ingredients into bottles
- ★ Tape for sealing bottles
- ★ Handouts or transparency of Bottle Key ***
- ★ Clay (or Sculpey, for a more permanent model) of 5 or more different colors to represent different elements – enough to create the stellar core and several small balls for each element (see preparatory procedure for amounts)

** Choose one with the fewest artificial ingredients so that the students will recognize the ingredients. This activity will work best if you choose something that is as uniform looking as possible. Other food items such as brownies (brownium) or bananas (bananium) can also be substituted for the pound cake. If you are unable to have food in your classroom, or if food allergies are a concern, you can do this activity with a sponge (spongium), styrofoam (styrofoamium), playdough (pladoium), or some other substance that can be easily cut or broken, and with easily recognizable properties. If you make a substitution of any kind, keep in mind that it must be dense enough to not fall apart when cut.*

*** Information about where to purchase this can be found in Appendix B.*

**** You can laminate these handouts if you want to use them with other groups. You only need to hand out one of these sheets per group of students.*

***** Food and allergy note: these items remain in a closed bottle for the entirety of the activity and thus are not handled by the students or loose in the classroom. If this is still an issue, we are working to develop a non-food alternative.*

Background

Atom: The smallest particle of an element that still has the characteristics of that element

Element: A *material* consisting of all the same atoms

Molecule: Two or more atoms of the same or different elements that are chemically bound together

Compound: A *material* consisting of atoms of two or more different elements that are chemically bound together

The copper/other pure element used here is an element, while the pound cake is a compound since it is made of many different substances (or elements).

We are made of star stuff!

The lightest elements (hydrogen, helium, and some lithium) were created in the Big Bang. Then, as the Universe cooled, matter clumped together to form stars.

Stars are big balls of hot gas, mostly hydrogen. Stars generate energy by converting lighter elements to heavier elements by a process called "nuclear fusion" in their cores. Elements are made of atoms, and atoms are composed of a central "nugget" called the nucleus that is composed of protons and neutrons. A cloud of one or more electrons surrounds this nucleus. An element is characterized by the number of protons in its nucleus, that is, different elements have different numbers of protons in their nuclei. For example, hydrogen has one proton, helium has two protons, oxygen has eight protons, and so on.

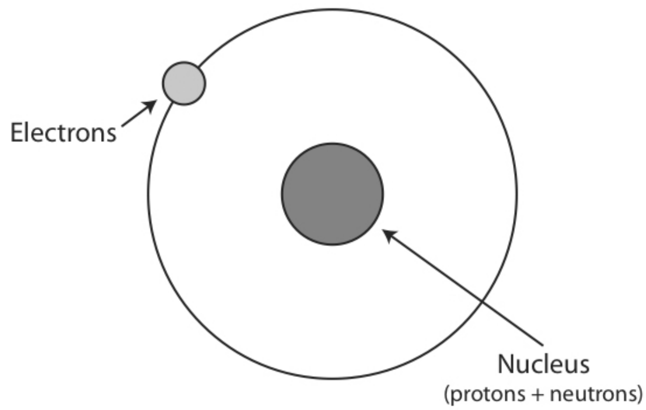
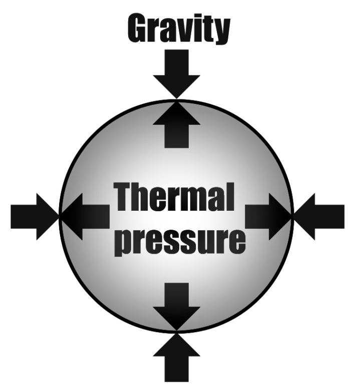


Diagram of an atom

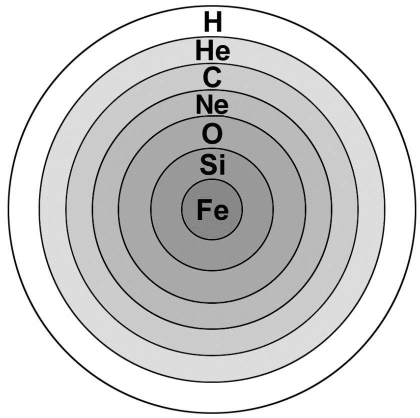
Nuclear fusion is the process by which the nuclei of two atoms come together and merge, forming a new nucleus. Since an element is defined by the number of protons in the nucleus of each of its atoms, nuclear fusion invariably converts one or more elements into a totally different element when the protons of the two original nuclei are combined in the new nucleus. During most of a star's life, energy is generated by the fusion of hydrogen nuclei (consisting of just one proton and no neutrons) into helium nuclei (consisting of two protons and two neutrons). It takes four hydrogen nuclei to produce one helium nucleus (and, in the process, two of the protons undergo a conversion into neutrons). The energy generated by the fusion flows outward and counterbalances the inward pull of gravity on the star. Stars spend the majority of their lives with these two forces in balance.



The balance of forces within a star.

Stars go through a cycle of "birth" and "death," but the timescales involved are much longer than what we associate with living things. Young stars are born in a cloud of gas and dust called a nebula. Particles inside these nebulae collide and clump together to form stars. When enough material has accumulated, the pressure and temperature in the core exceeds a critical threshold and fusion begins. A star is born!

The lifecycle of a star depends on how massive it is. All stars start by fusing hydrogen into helium in their cores, but eventually this fusion ends. If the star has sufficient mass it goes on to the next stage of fusion, where helium is fused into carbon. More massive stars can do this because their higher temperatures and pressure in their cores allow them to fuse more and heavier elements than their less massive counterparts. In stars like our sun, the fusion process ends after fusing helium, but in massive stars the process continues to fuse more elements. Depending on its mass, the star may go through successive periods in which carbon is fused into neon, neon into silicon, and silicon is fused into iron. The sequence of nuclear fusion stops with iron, even in the most massive of stars, because fusing iron into the next element requires an <u>input</u> of energy rather than resulting in a release of energy. At this point, the star has developed an "onion-shell" structure in which an iron (Fe) core is surrounded by a ring of silicon (Si), then a ring of oxygen (O), a ring of neon (Ne), a ring of carbon (C), a ring of helium (He), and finally a ring of hydrogen (H), as illustrated below.



A diagram illustrating the "onion" structure of a star.

Though the formation of elements heavier than iron requires more energy than a star has, the explosion of a star at the end of its life (a supernova) provides the energy necessary to make the much heavier elements. A supernova explosion also throws all of the elements created in that star out into space where new star systems can use them in their own formation processes. This explosions will be discussed in more detail in the activity called Supernova Explosions.

We know the Sun is a later-generation star because it has those heavier elements (we know that from spectroscopy, among other ways). So the elements in our bodies - like carbon, hydrogen, nitrogen, oxygen, and trace amounts of many others - came from the explosion of earlier stars!

Preparation

1. Universe of Beads: ~15 minutes

   In this activity, each element is represented by a different color of bead. Mix the ingredients ahead of the planned activity in a large bowl. Using the same, or larger, size "measuring cup" for preparation as the students will each have during the activity. Mix the following:

   - 50 scoops of clear beads (to represent 90% abundance of hydrogen in universe)
   - 5 scoops of light blue beads (to represent 9% abundance of helium)
   - 3 scoops of dark blue beads (to represent 0.08% abundance of oxygen)
   - 2 scoops of black beads (to represent 0.03% abundance of carbon)
   - 1 scoop of green beads (to represent 0.01% abundance of nitrogen)
   - 1 scoop of orange beads (to represent 0.01% abundance of neon)
   - 1 scoop of pink, purple, red, and yellow beads in roughly equal amounts (to represent 0.01% abundance of magnesium, silicon, iron, and sulfur together)

2. Bottle Activity: ~4 hours

In this activity, each element is represented by a different food. Prepare mixtures of these items according to the recipes below for the sources we are modeling. Note that these abundances are *by volume*, not weight. Because these items are approximately the same size, using dry measurements (volume) is very roughly equivalent to measuring numbers of atoms.

The number of bottle sets that you make is somewhat discretionary. The more sets you have, the smaller the group students can work in. 3-4 students working together is ideal. For a group of 25 students, that would be 6-8 bottle sets.

Place each mixture into a separate jar or bottle (these recipes are scaled for 8 oz. plastic bottles, available from many online suppliers). In each set, label each bottle with a number correlating to a specific source, and then record the key for later identification (ex. #1 = supernova). Cap all the jars/bottles. Taping shut the bottles when you are done can help to ensure that no food items escape into the classroom if this is a concern, as well as discourage students from opening the bottles, which may disrupt the activity and ruin the bottles for use at future events.

For each source, the recipes give the abundance (in %) and the volume of each element required in dry-measured cups (C), tablespoons (tbsp), and teaspoons (tsp). Note that the percentages may not add to 100% due to rounding amounts and excluding less significant elements.

Carbonaceous Chondrite (a type of meteorite)

O	44.3%	5 tbsp + 2 tsp	Brown Rice
H	30.8%	4 tbsp	White Rice
Mg	6.2%	1 tbsp	Red Beans
Si	5.5%	1 tbsp	Pinto Beans
Fe	4.9%	2 tsp	Red Lentils
C	4.2%	2 tsp	Black Beans

Supernova Remnant

O	42.2%	5 tbsp	Brown Rice
Fe	36.7%	4 tbsp + 3 tsp	Red Lentils
C	11.1%	1 tbsp + 1 tsp	Black Beans
Si	3.7%	2 tsp	Pinto Beans
Mg	2.8%	2 tsp	Red Beans

Human Body

H	61.6%	1/2 C	White Rice
O	26.3%	3 tbsp + 1 tsp	Brown Rice
C	10.0%	1 tbsp	Black Beans
N	1.5%	1 tsp	Brown Lentils

The Sun

H	92.1%	1/2 C + 3 tbsp + 1 tsp	White Rice
He	7.8%	4 tsp	Green Split Peas

Earth's Atmosphere

N	78.0%	1/2 C + 1 tbsp	Brown Lentils
O	21.0%	2 tbsp + 2 tsp	Brown Rice

Ar	1.0%	1/2 tsp	White Beans

Universe

H	90%	1/2 C + 2 tbsp	White Rice
He	10%	5 tsp	Green Split Peas

3. Clay star: ~2 hours to assemble

For this demonstration, we use the following color correlations as an example, but the colors can be changed. Regardless of the colors you use, it is easier to see the layers if adjacent colors contrast with each other.

Clay Color	Element
Red	Hydrogen
Yellow	Helium
Orange	Carbon
Green	Oxygen
Blue	Neon

Make the clay star in 5 color-coded layers.

- Start by making a ball about 2 inches in diameter using the blue clay
- Completely cover that ball with a layer of green clay about an inch thick
- The next layer will be orange in color with a shell thickness of ~ 1 inch
- The next layer will be yellow in color with a shell thickness of ~ 2 inches
- The next layer will be red in color with a shell thickness of ~ 2-3 inches

Example clay core model using our example colors

You may make this model out of Sculpey instead of clay if you would like a more permanent version. If you pursue this course, you should cut this model in half before baking it. This step can wait until the demonstration if you are using clay, but we found that pre-cutting the ball as the layers were added can be helpful for the demonstration because clay can be very hard to cut through.

This Sculpey model uses different colors for the same effect.

Make extra fusion demonstration small clay balls

- 4 red ~ 1 inch in diameter for hydrogen
- 3 yellow ~ 1.5 inches in diameter for helium
- 1 orange ~ 2 inches in diameter for carbon

Clay core with extra element balls

Activity

<u>Demonstration: Poundcakium</u> <u>(approximately 15 minutes)</u>

Ask the students if they know what an element is. We are going to do a demonstration to explore this concept.

We'll start this activity with a pound cake. Show it to the students and tell them that we are going to pretend we have just discovered this new element. We'll call it "Poundcakium." Ask the students what some of its characteristics are. Let the students answer. They will hopefully come up with answers about it being all one flavor, texture, and color (at least on the inside).

Next, cut the loaf of poundcakium in half. Ask the students what we have now? We still have poundcakium, albeit two pieces of it. Does it still have the same flavor, texture and color as poundcakium? Yes, because it is still poundcakium.

Now cut it in half again, and once again ask the student what we now have. Once again, it's still poundcakium, with all the same characteristics. Continue this process for one or two more cuts. The students should get the idea that no matter how many times the poundcakium gets cut in half, it remains the same.

If you were to continue to cut it in half, you would eventually get to single crumbs. Ask the students if you would have destroyed or created any poundcakium as you did this? Does it become something else other than poundcakium by cutting it? The answer is no.

This is the very basis of the idea of elements. An element is a material made of atoms of a single type, like carbon or hydrogen. Elements are the building blocks for matter - everything that we can see and touch.

You can now have volunteers hand out pieces of the pound cake to the students as a snack while you continue the discussion.

Discuss with the students how many things are made of more than one ingredient. Ask them what they think the ingredients are in pound cake (which you used to represent poundcakium). Let them answer, then read through the pronounceable ingredients on the pound cake label. Tell the students that flour, sugar, milk, and eggs (or whatever the recognizable ingredients are) are made of elements such as carbon and hydrogen.

Ask them to come up with examples of elements that they know from everyday life – things around your house or room? What about in Earth's atmosphere? Allow them to answer. If they need prodding, suggest categories, such as 'things around us in the room,' 'things in your home,' 'metals used for money or jewelry,' etc. Guide the conversation, but let it go where they take it. (examples: aluminum in soda cans, silver/gold in jewelry, diamonds (carbon), iron in steel, hydrogen and oxygen in water - "lead in pencils" should be corrected to "carbon (in the form of graphite) in pencils")

Pass out the individual copies of the periodic table, and put up the poster of the periodic table. Point out carbon and hydrogen. See what else the students recognize. Are there things on the periodic table that surprise them? Ask them what their favorite element is.

Hold up one of the pure element examples from your density cube set (or an alternate example of a pure element such as a copper tube).

Tell them that copper (or aluminum or iron, etc) is an element that occurs naturally on Earth.

Say that copper is very hard to cut, but in theory we could do the same thing we did with poundcakium. If we could cut the copper in half, would it be a different substance? No, it's still the same thing, with all of the same properties. Since copper is an element, no matter how many times it's cut it in half, we will always be copper.

We could cut the copper in half and in half again until all we were left with was a single atom of lead. An atom is the smallest piece of copper, or any element, that we can have that still has the same properties as the original piece.

An element is a chemically pure substance composed of atoms of a single type. Elements are the building blocks for all matter, everything that we can see and touch. Copper is an element that we can find naturally occurring on Earth. All copper atoms are the same.

Refer back to the periodic table. The elements known to scientists are cataloged in this table. The elements in the rows and columns of the tables have common traits or characteristics. Each element is different from the next in many measurable ways. Some are solid, some are gas, and some are liquid. They each have a unique mass. They can all be described with qualities like hardness or softness.

Some elements are common to us in their pure form, like silver or gold. Some are common to us in compounds like salt (NaCl) or water (H_2O).

Ask if poundcakium is an element or a compound. Wait for responses with explanations. They should answer that we were pretending that it was an element for our purposes.

Now ask if the pound cake is an element or compound. Again, wait for responses with explanations. The answer is that it is a compound, because it's made of more than one element.

Activity: Universe of Beads (approximately 15 minutes)

Ask the students what they think is the most common element in the universe? Let the students give some guesses.

Ask what they think we would have if we were able to go out and grab a handful of space particles. Let the students give some guesses. Tell them that we will explore these questions through an activity.

Tell the students that you have a Universe of Beads, which is a model of the percentages of all the elements in the universe. Each student will take a random scoop of the Universe of Beads, and will count or estimate how many of each bead color (element) they have. A white napkin or piece of paper provides a good surface for the student to sort and count their sample, and allows for easier recollection of the beads after the activity.

Give the students 5-10 minutes to get a scoop and to inventory their ingredients.

Make a tally on a white board, easel pad, or overhead projector of the counts from each student. Observe which color they had the most of. See how many of them had hydrogen? Helium? Carbon? How about Oxygen? Nitrogen? Iron?

Most, if not all, students should have more beads representing hydrogen than any other element. They should also mostly have helium represented in their sample. After that, everything is probably quite variable. Find out if anybody had all of the elements represented. Did anybody have the exact same distribution as one of their neighbors? This is very symbolic of the universe as a whole. Different corners of the universe are made of different things, but hydrogen is very prevalent everywhere.

Hydrogen is the most abundant element in the universe and the first element on the periodic table. Almost 90% of the universe is hydrogen. The second most abundant element is helium. Nearly 10% of the universe is helium. All of the other elements exist in much lower abundances, much less than 1%. Carbon, nitrogen, oxygen, magnesium, silicon, and iron are some of the common and more abundant heavier elements in the universe.

Activity: Element Bottles (approximately 15 minutes)

We are now going to look at the elemental distributions of some specific objects in the universe.

Give one set of bottles and a key to each group of students. Have students estimate the composition of the bottles by giving the percentage of hydrogen, percentage of helium, etc. See if they can match the element bottles with the different types of objects listed on the key.

Note that the students have one more bottle than the list of objects would indicate. The final bottle is a mystery bottle. Encourage students to identify the elements they see in this bottle, and then to ponder what those elements could form. The mystery bottle is made of hydrogen, oxygen, carbon, and nitrogen – the elements used in living creatures. Students might guess this bottle represents plants, animals, sea water, soil, etc. This bottle actually represents the *human body*!

- The bottles for the Sun and the Universe look nearly identical – students may complain that they have two of the same bottle! But the primary elements in a star and the entirety of the Universe are identical: hydrogen and helium. Students may claim to be able to distinguish these two bottles and "solve" them, but the amounts are so similar that the bottles are interchangeable.

- A key point of this activity is comparing and contrasting the composition of these objects on Earth and in space. Ask follow-up questions: *What do all of the bottles have in common? What makes each one stand out? Does this surprise you? Did you know that you are made of "star stuff"?*

What are your bodies are made of? Let the students answer. Water (which has a lot of oxygen!), carbon, nitrogen, etc. How did we come to have this rich selection of elements on Earth? How do we go from mainly hydrogen and helium to all of these elements we need to build people and plants?

Discussion: Where do elements come from? (approximately 15 minutes)

Ask the students what they know about atoms (if anything), and see what their answers are. If they don't mention protons and electrons, just leave them out, but if they do mention them, you can say that an element is defined by the number of protons it has in its nucleus.

Ask where the elements come from. In the Big Bang, hydrogen (H) - the lightest element, and helium (He) - the second lightest, were created. This is partly why there is so much of these elements in the Universe. The Universe today is about 90% hydrogen and almost 10% helium. All the rest of the elements make up much less than 1% of the Universe. (A very small amount of lithium - the third lightest element – was also created in the Big Bang, but mention this only if it comes up in discussion.) But where does everything else come from? See if anybody has any ideas.

Diagram of hydrogen and helium atoms.

All of the other elements come from stars, but how? The center of a star is very hot (millions of degrees) and very dense. This means that there's a lot of stuff in too small of a space. Draw an analogy to cooking. Ask them what happens when you cook. They probably know that you mix and heat ingredients, and get something new. This is a good analogy to what happens in a star. The process of fusion releases energy. And it is this energy that makes the Sun and all other stars shine. This keeps the balance in the star – the energy generated by the fusion flows outward and balances the pressure inwards from the force of gravity so the star doesn't collapse.

In the early life of a star, there is a lot of hydrogen in the center, and all those hydrogen atoms bump into each other. Often, some of them will stick together, and this is called fusion.

Demonstration: Fusion (approximately 15 minutes)

Have student volunteers come up. Show the small clay balls representing hydrogen, and let the volunteer stick four of them together. The process of fusion releases energy. It is this energy that makes the sun and all other stars shine. When H fuses, it forms a new element. It forms He.

Diagram of hydrogen atoms becoming a helium atom.

Ask for another volunteer to come up. Now bring up a different color clay ball that represents helium. Let the student hold the helium clay ball. If you could change the color of the H clay balls as they join, you'd get this second color. Explain that this is what our Sun is doing now – fusing hydrogen to helium. It has been doing this for 4.5 billion years and will continue to do so for about another 5 billion years.

Although there is a lot of H in the star, at some point the H in the center runs out. When this happens the core of the star shrinks, causing the temperature to increases. Since it is now hotter, there is enough energy for the He to start fusing. When He fuses, C (carbon) forms. Let the second volunteer stick three helium clay balls together. Then, bring up the last small clay ball representing carbon.

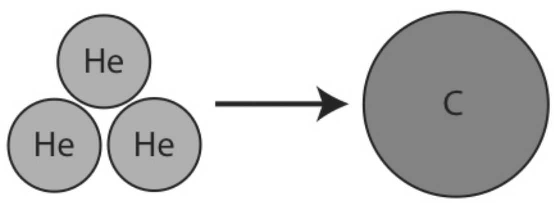


Diagram of helium atoms becoming a carbon atom.

This continues until the He runs out. For stars like our Sun, this is where the process stops. But in more massive stars, there is enough energy to continue the process. The more massive the star, the further the process can continue.

To compare the mass/size of the Sun to that of Earth, the Sun's mass is 330,000 times that of the Earth; the Sun's volume is 1.3 million times that of the Earth. What's more, a large star can be 15 times more massive than the Sun and have a volume 4000 times that of the Sun.

This process continues in the most massive stars until iron is created. Unlike the fusion processes up to this point, which release energy as part of the process, fusing iron requires an extra input of energy. This means that the creation of new elements in the cores of stars halts with iron, no matter how big the star is. (If they ask what is special about iron, it's because Fe (iron) is the most stable of the nuclei, and the process of fusion takes less stable nuclei to more stable nuclei.)

Now is the time to cut open the clay star model. At the end of its life, the center of a star will look like this. Have a volunteer student carry one half around the room so that each of the students can see it up close while you hold the other half for all to see. All the elements that the star has created in its lifetime are inside the star in concentric shells. Because the area of the most intense fusion is always at the core of the star, the outermost shell is made of hydrogen, the first element to be fused, and the innermost shell will be of the last element to be fused, which depends on the stars' mass (in this case, iron).

The number of element layers at the end of a star's life will depend on the mass of the star. For a star like the sun, there will only be two layers – hydrogen on the outside with helium on the inside. For the most massive of stars, the center will be iron with layers of all the other elements out to hydrogen on the outside. Our clay model is somewhere in between.

The colors of clay used in this model are not necessarily the color of the elements or the star. They are just bright colors used for the demonstration. The accompanying Supernova activity will illustrate what happens next in very massive stars. In particular, you will see how the elements get out of the center of this star and into space (where they eventually can become part of the earth and you and me).

Periodic Table of the Elements

Atomic Number: 6
Symbol: C
Name: Carbon

1 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Cesium	56 Ba Barium		72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium		104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Uun Ununnillium	111 Uuu Unununium	112 Uub Ununbium		114 Uuq Ununquadium		116 Uuh Ununhexium		118 Uuo

57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

PERIODIC TABLE

Atomic Properties of the Elements

- Solids
- Liquids
- Gases
- Artificially Prepared

Period																		
1	1 H Hydrogen																	2 He Helium
2	3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
3	11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
4	19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
5	37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
6	55 Cs Cesium	56 Ba Barium		72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
7	87 Fr Francium	88 Ra Radium		104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Uun Ununnilium	111 Uuu Unununium	112 Uub Ununbium		114 Uuq Ununquadium		116 Uuh Ununhexium		

Lanthanides	57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
Actinides	89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Atomic Number
Symbol
Name

58
Ce
Cerium

Universe of Beads

Dark Blue = Oxygen (O)

Pink = Magnesium (Mg)

Light Blue = Helium (He)

Black = Carbon (C)

Purple = Silicon (Si)

Orange = Neon (Ne)

Green = Nitrogen (N)

Clear = Hydrogen (H)

Red = Iron (Fe)

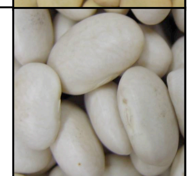
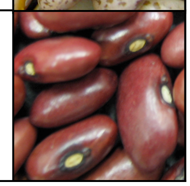
Yellow = Sulfur (S)

Universe of Beads

COLOR	ELEMENT	HOW MANY?
Clear	______________	________
Light Blue	______________	________
Dark Blue	______________	________
Black	______________	________
Green	______________	________
Orange	______________	________
Pink	______________	________
Purple	______________	________
Red	______________	________
Yellow	______________	________

Key for Bottle Activity

Hydrogen (H) White Rice	
Helium (He) Green Split Peas	
Oxygen (O) Brown Rice	
Carbon (C) Black Beans	
Iron (Fe) Red Lentils	

Nitrogen (N) Brown Lentils	
Argon (Ar) White Beans	
Silicon (Si) Pinto Beans	
Magnesium (Mg) Red Beans	

The Sun

Element	# atoms
H	92.1%
He	7.8%

Supernova Remnant

Element	# of atoms
O	42.2%
Fe	36.7%
C	11.1%
Si	3.7%
Mg	2.8%

Earth's Atmosphere

Element	# of atoms
N	78%
O	21%
Ar	1%

Meteorite

Element	# of atoms
O	44.3%
H	30.8%
Mg	6.2%
Si	5.5%
Fe	4.9%
C	4.2%

Universe

Element	# atoms
H	90%
He	9%

Rainbow Analysis

Summary

Students are introduced to the electromagnetic spectrum and the scientific tool of spectroscopy. They will each build a simple spectroscope with which they can examine the light from different light sources, particularly the Sun (if logistically feasible) and artificial lights (fluorescent or sodium lamps, discharge lamps, or whatever is available locally). The solar spectrum will appear continuous at the resolution typical of plastic diffraction gratings; however, the fluorescent or sodium room lights and discharge lamps will show clear spectral lines (students often describe the spectra as "broken up"). These lines represent the "fingerprint" of the particular element contained in the lights and are always the same, no matter where the element appears or how much of the element is present. The appearance of a given fingerprint in the spectrum of a distant astronomical object demonstrates the presence of that substance in the object. The discharge lamps provide the opportunity to show students a variety of spectral fingerprints.

Objectives

- ★ To understand that light is composed of different wavelengths of energy, including many we cannot see with our eyes
- ★ To recognize that light can be separated by wavelength, which is equivalent to color
- ★ To build an astronomical tool, specifically a spectroscope, to study light
- ★ To learn that elements and molecules each have a unique "fingerprint" of lines at different wavelengths

Materials

- ★ Paper towel tubes (1 per student; any tube of a similar dimension, such as PVC piping, shipping tubes, etc, will work just as well for this, so the primary factor is ease of acquisition)
- ★ Aluminum foil (2 pieces at 4 x 4 inches and 2 strips at 1 x 3 inches per student; measurements are approximate and do not need to be exact)
- ★ Diffraction grating (approximately 1 inch square of material per student) *
- ★ Masking tape
- ★ Poster or handout about the electromagnetic spectrum (an example can be found following this session)
- ★ Example spectrum (a handout can be found following this session)
- ★ Light sources
    - ★ Incandescent light bulb as a source of a continuous spectrum **
    - ★ Discharge lamps (optional; examples: H, He, O, N, Ne, H_2O, and CO_2) ***

** Information about where to purchase this can be found in Appendix B.*

*** Common household bulbs are incandescent or flourescent light sources. If you don't know what kind of lamp you have, build a spectroscope and look at it. Descriptions of the spectra of common types of lights are at:*

http://isaac.exploratorium.edu/~pauld/summer_institute/summer_day9spectra/spectra_exploration.html

**** Distinct lines are produced by light sources from only one element or compound. Discharge lamps are the best for this, but most institutional buildings have mercury fluorescent lamps that will work if discharge lamps are not practical for your purposes. You will want to have as many different sources of this type as possible, for increased student interest and understanding, but even one helps. Information about where to purchase discharge lamps can be found in Appendix B.*

Other Requirements

- ★ A room that can be darkened (preferably completely darkened)

Background

Element: A material consisting of all the same atoms

Examples:
- Pure gold
- Silver
- Copper
- Aluminum
- Oxygen

Compound: A material consisting of atoms of two or more different elements that are chemically bound together

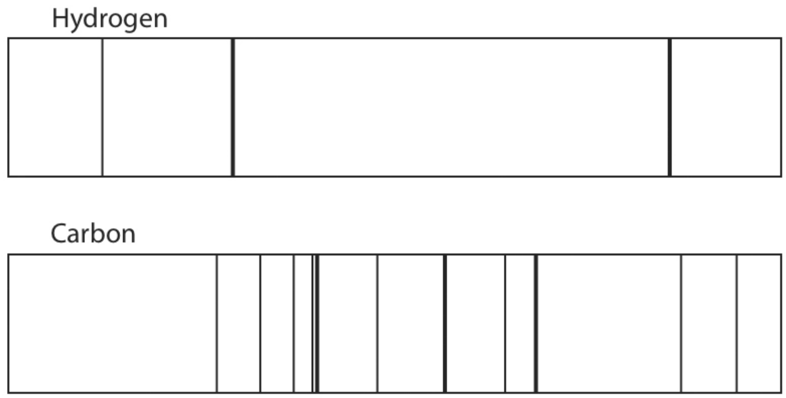
Examples:
- Water (hydrogen + oxygen)
- Table salt (sodium + chlorine)
- Ammonia (nitrogen + hydrogen)
- Sugar (carbon + hydrogen + oxygen)

"**Spectra**" is the plural of "**spectrum**."

A **diffraction grating** separates the light from a source into the full range of visible light, similar to what a prism does, making it possible to see individual lines in the source's spectrum.

The light from each element or compound produces a unique pattern of lines within the spectrum (a "fingerprint" – not a technical term, by the way) that identifies its presence. The lines are always in the same place for that particular element or compound.

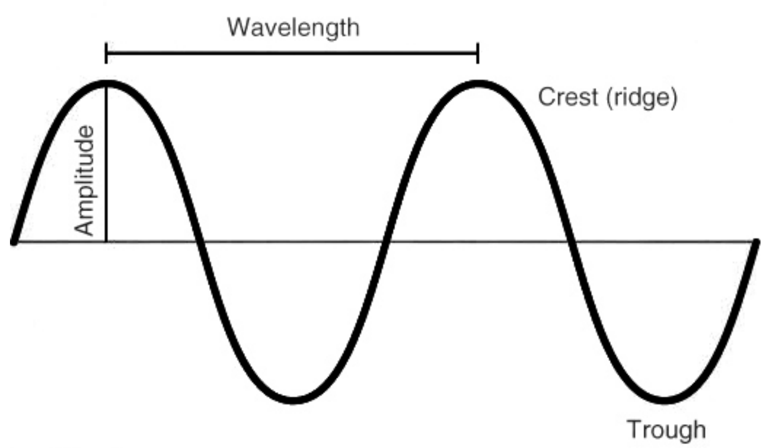
If the fingerprint of a specific element or compound is in the spectrum of a distant astronomical object, it is evidence that that element or compound is present in that object.



The spectra of hydrogen and carbon, illustrating how different two different elemental spectra can be.

Sunlight is a white light, which means that it is a combination of all the colors of visible light. When you look at its light through a spectroscope, its spectrum is continuous, rather than having distinct lines. We see an example of this when we see rainbows in the sky. These result from sunlight being diffracted (spread out) by water droplets in the air.

When we talk about light, **wavelength** refers to the distance between the two peaks (or crests) of the light wave.



A diagram of terms with regard to a wave.

Longer wavelengths correspond to shorter frequencies. So, the wavelength or frequency of light is a characteristic that defines what type of light it is (radio, microwave, infrared, visible, ultraviolet, X-ray, or gamma-ray). Note that scientists often use the word "light" to refer to energy in any wavelength – not just the visible range.

Element discharge lamps are the best way to show students the fingerprints for specific elements. These very specific lamps send an electrical charge through the gas of a certain type of element. The resulting light will show the signature spectrum, or fingerprint, of that element. Viewing them is best done in a completely darkened room. Covering bulbs with colored paper or using colored bulbs **will not change** the spectral lines of a clear bulb because the source of the light is the filament, not the glass of the bulb.

We use a narrow slit to select what we want to look at and adjust the size and shape of its spectrum. The diffraction grating at the other end of the device spreads the incoming light in a specific direction. During the calibration, we line the slit up so that it is perpendicular to this direction in the diffraction grating. In this way we limit the data that contributes to our spectrum. If we did not do this, the spectrum for any extended object, such as a galaxy, would be hopelessly jumbled and impossible to interpret.

Preparation

1. Prepare parts of the spectroscopes: approximately 30 minutes

   Cut pieces of foil (2 pieces of 4 x 4 inches and 2 pieces of 1 x 3 inches per student) and diffraction grating (a 1-inch square of diffraction grating per student). Exact measurements are not at all necessary. Collect one paper towel tube for each student. You can put each kit in a Ziploc bag.

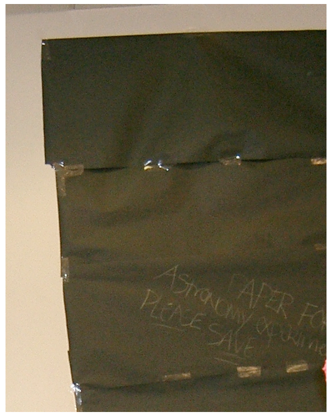
   Handle the diffraction grating carefully with clean hands (or gloves), touching only the edges. Avoid smudges and fingerprints, which will negatively affect the function of the spectroscope.

2. Build example spectroscope(s): approximately 15 minutes

   This accomplishes two things. First, it makes the activity much easier for when you go through it with students. Second, it can help the students to see an example of a spectroscope that is already assembled.

3. Darken the room: approximately 10 minutes (depending on room)

   The room should be capable of going from brightly lit to dark so that both the overhead fluorescent lamps and the narrow discharge lamps can be seen effectively. Sometimes this means lights or light leaks must be covered. Dark black plastic trash bags and duct tape have proved useful for this.



Activity

<u>Talking Point: How do we know what we know?</u>

Discuss the following questions with the students:

What do astronomers study?

How do astronomers learn anything about the things they study?

Do we take pieces of stars and planets and put them under a microscope in our lab?

What do you think is the most distant astronomical object from which we have a physical sample?

- ★ Right now it's a comet tail
- ★ We also have collected samples from the moon
- ★ Soon we will add Mars to this list

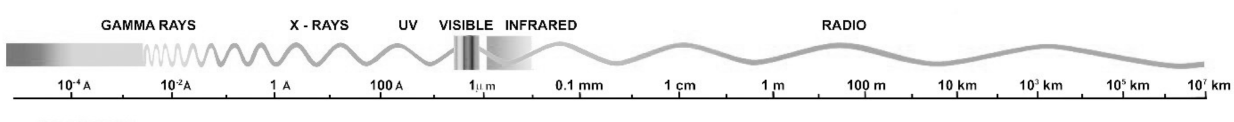
So since we can't collect pieces of more distant objects, how do we learn about them? The only thing we get from distant objects – the only thing that can traverse such vast distances – is light.

<u>Talking Point: Spectroscopes</u>

Ask if students know what a "spectroscope" is:

spectro – from spectrum, or rainbow (show an example)
scope – a viewing instrument, as in telescope or microscope
spectroscope – an instrument for viewing spectra

Ask them if they know what a spectrum is - the range of all the wavelengths of energy possible, from the shortest wavelengths (highest energies/frequencies) to the longest wavelengths (lowest energies/frequencies). Visible light is just a small part of the entire electromagnetic spectrum.



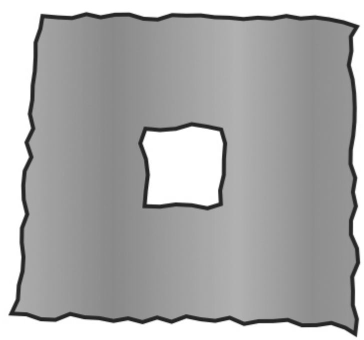
Note that scientists often use the word “light” to refer to energy in any wavelength – not just the light that we can see with our eyes (visible light).

Pass out the handouts of the electromagnetic spectrum or put up the poster. Point out the full spectrum and have a student find the small portion that is visible light. Discuss what **wavelength** means, and how wavelength corresponds to energy/frequency range.

Activity: Construction of the Spectroscope (~20 minutes)

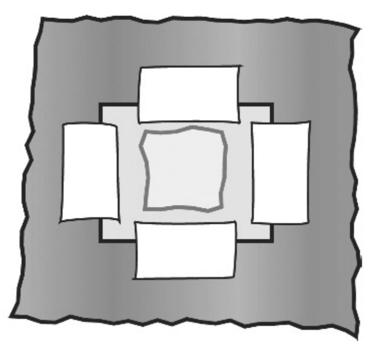
1. The spectroscope has two ends, one for the diffraction grating (which is the end you look through) and one for a slit, which controls the entry of light into your instrument so you can select which object to look at and improve the dispersion of light into a longer spectrum. We will assemble the grating end first.

2. Students should take one piece of aluminum foil about 4x4 inches and tear or cut a small hole in the center of the foil. The hole should be smaller than the square of diffraction grating material. A hole in between a nickel and a dime in size is usually good. The easiest way to do this is to fold the foil square in half, and then in half again the other direction. Cut or tear off the corner that is at the center of the foil and then unfold the foil – voila!



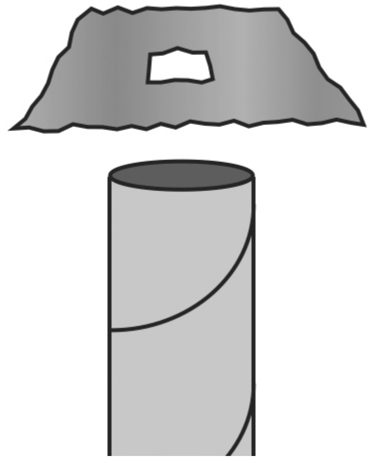
A tinfoil square with a hole in the center.

3. Again, being careful to handle the diffraction grating only by its edges, tape it over the hole. Tape only the edges of the grating, not across the middle. It doesn't matter which side of the grating or the foil is up/out.



Diffraction grating taped over the hole in the tinfoil square.

4. Students should then center this foil-mounted grating over one end of the tube, taped side in, and tape it to the outside of the tube at its edges.

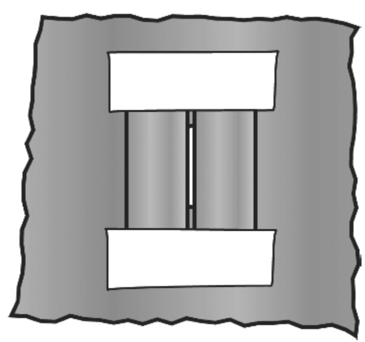


Placing the diffraction grating over the end of the tube.

5. Next we will assemble the slit end of the scope. Students should take the other large piece of aluminum foil and put a hole in the center of the foil as before (if the hole they made the first time was a little too large for the diffraction grating, the piece of foil can probably be recycled for the slit end, as long as the hole is smaller than the end of the tube).

6. Students should take the two 3x1-in strips of aluminum foil and carefully fold each of them in half along the length. Make a sharp crease at the fold of each.

7. Take the two creased pieces of foil and lay them over the hole in the large piece of foil – the two creased edges should face each other without overlapping – a gap of a few millimeters (or perhaps the width of a toothpick) is perfect. Tape the two creased pieces of foil in place over the hole (but make sure that the tape isn't covering the gap).



Construction of the slit end of the spectroscope.

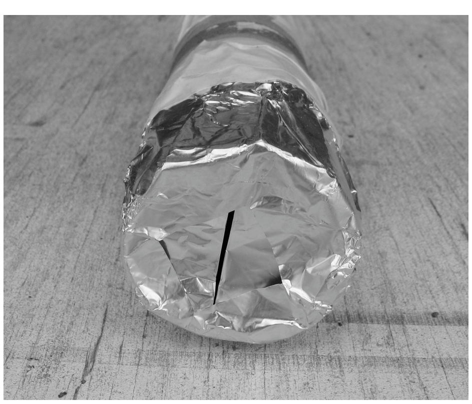
8. Place the slit over the open end of the paper towel tube, taped side in (for structural stability) and wrap the aluminum foil around the tube - BUT DO NOT TAPE THE SLIT TO THE PAPER TOWEL TUBE YET! The slit allows you to select what you want to look at and adjust the size and shape of its spectrum.

9. Now we need to **align** (or precisely adjust) our spectroscope. We want to align our slit with the diffraction grating so that we get a wide spectrum, which will be easy to see.

   Hold the spectroscope so that you can look through the diffraction grating end (the plastic square should be about as close to your eye as your glasses' lens or as close as you would put a microscope). Point the slit end of the spectroscope towards a light source – this can be a light in the room or if you are outside, at the SKY, but NOT the SUN! Look for a rainbow in the spectroscope, probably a little bit off to the side or up or down (you should be able to see regular light from your source coming through the slit, but the rainbow will be off-center).

   While still pointing your spectroscope at the same light source and holding the tube steady, twist the slit around until the rainbow is as "fat" or "tall" as you can make it. (Conversely, you can twist the tube while holding the slit end steady – either is equally effective.) Once you are satisfied, tape the foil of the slit end into position.

10. That's it! Make the point to the students that since they've built this spectroscope themselves, they know how to fix it if it breaks – if the aluminum foil tears, or they accidentally sit on their paper towel tube, or some of the tape comes off, they can fix it themselves!



<u>Remind them **NEVER** to look at the sun!</u>

<u>Activity: Using the Spectroscope (~15 minutes)</u>

1. Now that the spectroscopes are built, it's time to put them to some use – the first spectrum students should look at (if at all possible) is that of the sun.

   <u>IMPORTANT WARNING: NEVER LOOK DIRECTLY AT THE SUN WITH THIS INSTRUMENT OR YOUR NAKED EYE.</u>

   Instead of looking directly at the sun, we can look at the sky, which is bright from sunlight scattered off of little bits of dust in the air. This should be possible even if it is fairly cloudy. For added safety, you can also see a solar spectrum by looking through the spectroscope at a white piece of paper that is reflecting bright sunlight. However, neither of these methods may be feasible if it is actually raining, in which case an incandescent bulb can be substituted. At this resolution, both the solar spectrum and the spectrum from an incandescent bulb are fairly uniform rainbows, showing all the usual colors (the students will usually remember and recognize ROY G BIV).

   Now is also a good time to point out (in conjunction with a spectrum poster or handout) that the spectrum really extends beyond what the students can see in their spectroscopes, to "invisible light", like radio, infrared, ultraviolet, X-ray, etc. This is similar to sound of a dog whistle – the sound a dog whistle makes is real, but it is only audible with the proper kind of ears (like dogs' ears!). Similarly, radio, IR, UV, X-ray, and other wavelength of light are real, and with the proper kind of "eyes" or cameras we can see these other wavelengths of light. If you think of light in terms of keys on a piano, the light we can see is only the keys from middle-C up to E—less than a full octave. Everything else is invisible light.

   Different colors that the students see represent different wavelengths of light, but visible light wavelengths have a very narrow range – only about 300-700 nanometers (a nanometer is a billionth of a meter) – while wavelengths of light can range from many meters in the radio to less than a picometer (trillionth of a meter) for gamma rays.

2. Next, students should examine a light source with obvious discrete spectral lines – most schools and other institutional buildings have bright mercury (or other) fluorescent lamps, which are ideal. If

you are unsure of what kind of lamps you have, build yourself a spectroscope in advance and have a look around – descriptions of the spectra of common types of lights can be found at:

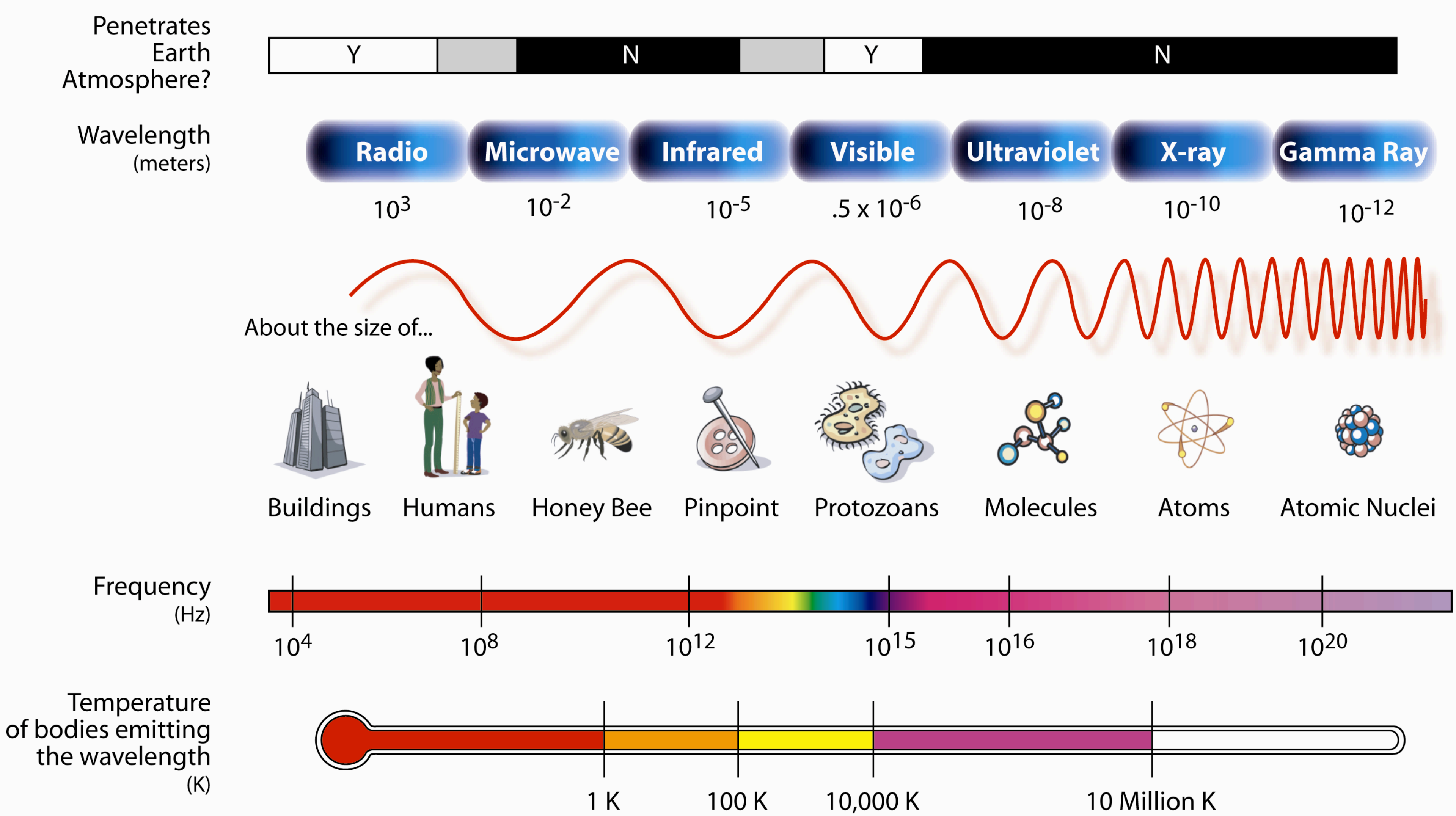
http://isaac.exploratorium.edu/~pauld/summer_institute/summer_day9spectra/spectra_exploration.html

Ask students what differences they notice between the solar spectrum and the spectrum of the artificial light. Prompt them, if necessary, with the question "Are all of the ROY G BIV colors present in this new spectrum?" For mercury fluorescent lights, there will only be a faint continuum, but there will be four or five bright lines (depending on how far red your eyes can see): 1 or 2 will be red, 1 will be green, and 2 will be blue/violet. Some colors are missing in the spectrum and some appear as very strong, clear lines – these lines are the fingerprint of mercury. If you see these lines, there is mercury in your light source. If you don't see them, there is little or no mercury. This is how astronomers figure out what distant objects are made of – every atom and molecule has its own unique fingerprint, and based on the brightness of the "fingerprint", we can even tell how much of an atom or molecule is present (lots of "stuff" means bright lines, very little "stuff" means faint lines).

3. If time and resources permit, you can show students other light sources containing other molecules and elements (e.g. with discharge tubes) to show them what some of the other fingerprints look like. Hydrogen and helium are good elements to start with, because their spectra are very simple. Regardless, you should send students home with their spectroscopes and encourage them to check out the lights in their local neighborhoods – most street lamps are either mercury or sodium lamps, and "neon" signs often contain many different elements which produce different colors (only the orangey-red ones are actually neon). The website mentioned above would be a useful guide for their own explorations.

Remind them again NEVER to look at the sun!

THE ELECTROMAGNETIC SPECTRUM



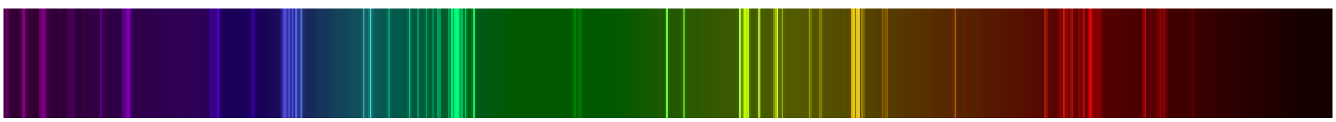
Spectra of Common Elements

Hydrogen

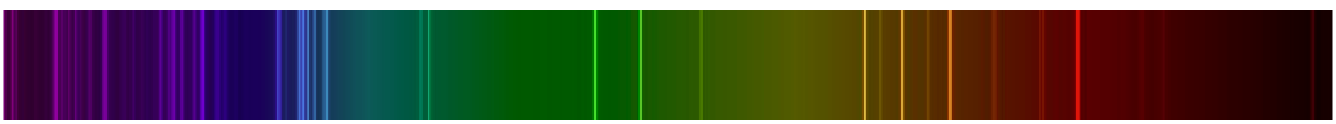
Helium

Carbon

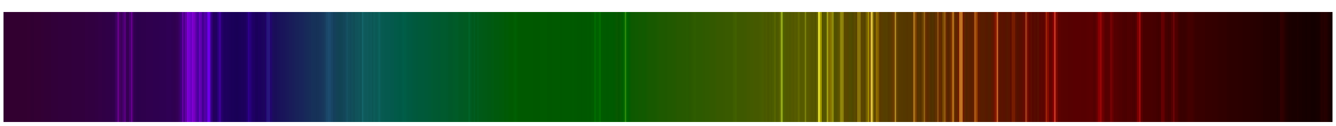
Nitrogen



Oxygen



Neon



Sodium

Mercury

Supernova Explosions

Summary

Students are reminded that the universe is made up of elements and that the heavier elements are created inside of a star, as they learned in the "Elements and You" activity. They are introduced to the life cycle of a star and to the way in which a star's mass affects its process of fusion and eventual death. The physical concept of equilibrium as a balancing of forces is discussed, and an experiment is conducted to demonstrate what happens to a soda can when the interior and exterior forces are not in equilibrium. An analogy is made between this experiment and core collapse in stars to show the importance of maintaining equilibrium in stars. Finally, it is demonstrated how mass is ejected from a collapsed star in a supernova explosion, thereby dispersing heavier elements throughout the universe.

Objectives

- ★ To introduce the life cycle of a star
- ★ To discuss the forces at work inside a star
- ★ To understand the role of mass in determining the extent of fusion and the fate of a star
- ★ To learn about core collapse of a star
- ★ To simulate mass ejection and understand how to populate the universe with the heavy elements from the interior of stars during a supernova explosion

Materials

- ★ Colored balloons (1 of each of the following colors: red, orange, yellow, green, blue, and violet)
- ★ Empty aluminum soda cans (needs to be clean and not at all crushed; we recommend having several)
- ★ Hot plate (or Bunsen burner and screen/ring setup)
- ★ Large, deep bowl of ice water
- ★ Tongs or oven mitts
- ★ Hoberman sphere ***
- ★ Basketballs (or kickballs, soccer balls, etc; ideally at least a few – the more you can get, the more students can participate at once) *
- ★ Tennis balls (approximately the same number as the larger balls – a few extra in case they get lost is a good idea) **
- ★ (Optional) Model clay star from Elements and You session

** This activity can also be done using smaller balls. Larger balls will bounce very high, which is more spectacular, but can cause damage if you are doing this activity indoors. With small balls it is possible to have an entire classroom set so that all girls can do the activity at once. It is a personal choice. If you choose to go with smaller balls, you will need tennis balls and ping-pong balls instead of basketballs/kickballs and tennis balls.*

*** If you are planning to run this program more than once, consider buying non-pressurized tennis balls. Pressurized ones will lose pressure with time, and will no longer bounce. Non-pressurized ones do not have this problem, and you will save money in the long run.*

**** Information about where to purchase this can be found in Appendix B.*

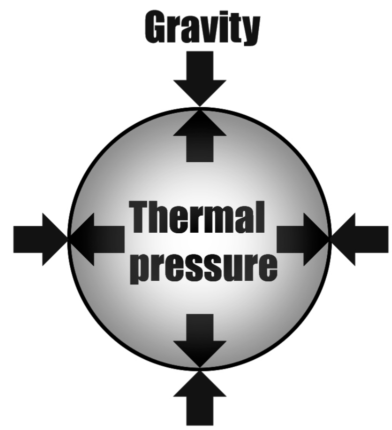
Background

Stars are big balls of hot gas, mostly hydrogen. Our Sun is a star, the closest one to Earth, and this is why it looks so much bigger and brighter than the other stars in the sky. Even though the sun may look small in the sky (compared to Earth), it is actually enormous! The Sun is about 330,000 times more massive than the Earth. Its radius is about a 100 times that of the Earth, which means that a million Earths can fit inside the Sun! Our Sun is large relative to the planets, but it is an average size compared to other stars. In the extreme, stars can be up to 100 times more massive than the Sun.

Astronomers classify stars by their spectra – the colors of light they emit. Most stars actually emit many kinds of light, but a star can look one color because that is the brightest part of its spectrum. When people first started looking at the spectra of stars, they looked especially at the amount of light coming from hydrogen. They called the stars with the most hydrogen emission type A stars, then type B, C, and so on. Later, people realized that thinking of classes of stars by their color made more sense and gave more information because blue stars are the hottest, brightest, and most massive stars, while red stars are the coolest and least massive stars. So, the classes (A, B, C…) were reordered, some of them dropped out, and we ended up with the order OBAFGKM (from blue to red, hot to cool, high mass to low mass).

Some kinds of stars and other astronomical objects are brightest in colors that we cannot see with our eyes, but that does not mean that they do not put out some light in the optical. Students probably talked about different kinds of light in the Rainbow Analysis activity. Astronomers have special cameras and telescopes that can look at different kinds of light to study different astronomical objects. Sometimes people also use these cameras on Earth, such as using "Night Vision Goggles" to let people see infrared light.

Stars generate energy by converting lighter elements into heavier elements through nuclear fusion in their cores. These elements are the "fuel" that generates a star's energy that then flows outward and counterbalances the inward pull of gravity. Stars spend the majority of their lives with these two forces in balance, as shown in the image to the right.

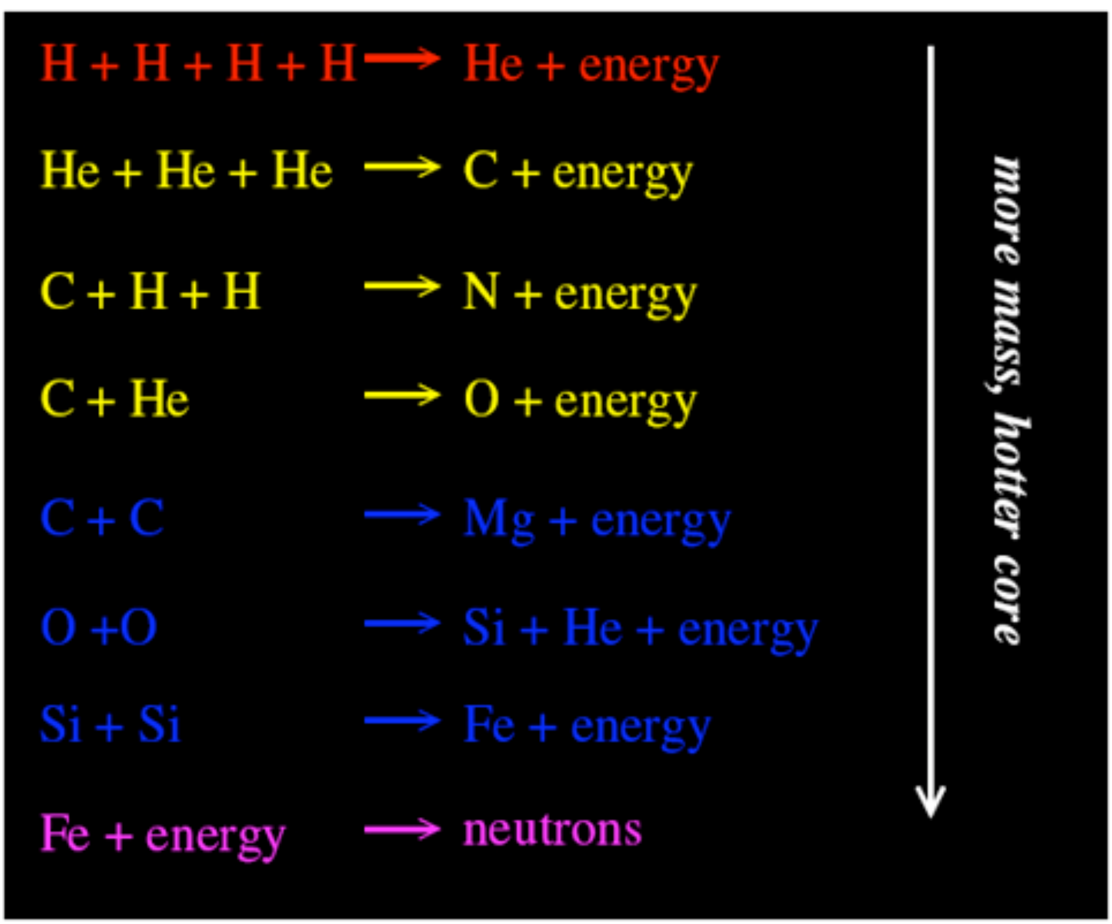


The balance of forces within a star.

Stars go through a cycle of "birth" and "death," but the timescales involved are much longer than what we associate with living things. Young stars are born in a cloud of gas and dust called a nebula. Particles inside these nebulae collide and clump together to form stars. When enough material has accumulated, the pressure and temperature in the core exceeds a critical threshold and fusion begins. A star is born!

The lifetime of a star depends on how massive it is. Small stars can live many billions of years, but the most massive stars will only live a few million years. Our Sun is a medium star that is about halfway through its life cycle after 4.5 billion years.

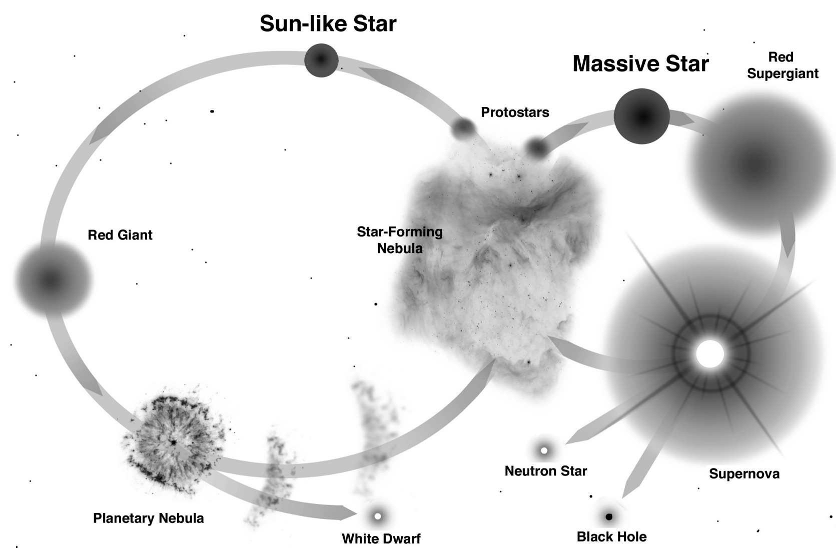
The following table shows simplified versions of the fusion processes that occur in different mass stars. The colors mostly correspond to the colors in the table in the Stellar Life Cycle section of this description except for violet. In the Stellar Life Cycle table, violet represents the very largest, hottest, most massive stars, but here violet represents the end stage of these very massive stars, in the supernova collapse.



All stars start out fusing hydrogen into helium, but the cool, red stars will stop after that and will not go on to fuse any other elements.

Stars of intermediate mass like our Sun are yellowish and spend the majority of their lives (many billions of years) in a stage of their lives known as the "main sequence," during which they fuse hydrogen into helium in their cores. Once this fusion ends, they expand into the "red giant" phase. When our Sun enters this stage of its life in 5 billion years the Sun will puff up so big that it will swallow the Earth. Our Sun will then have a brief phase in which helium is fused into carbon. Depending on their mass, some intermediate sized stars can go on to fuse nitrogen or even oxygen. After they run out of fuel that they can fuse, red giants blow off their outermost layers that then form a disk of material around the star called a "planetary nebula." These objects were originally named this because they look like a planet when seen through older telescopes, but in reality they have nothing to do with planets.

The hot core that is left behind is approximately the size of the Earth and is called a "white dwarf." White dwarfs are very dense — a teaspoonful of white dwarf material would weigh 15 tons on Earth! — and shine for many more billions of years as they slowly cool.



The lifecycles of both a small to medium star and a massive star.

The very hottest and most massive stars appear blue and can continue the process of fusion (in shells, as described in the Elements and You activity) until they are left with iron cores. Iron requires much more energy to fuse than the other elements did because it is the most stable element. In fact, more energy is needed to start the fusion process than it would actually produce. So instead of providing energy for the star like fusing other elements did, iron demands energy that the star can't afford, and therefore the iron core doesn't fuse into another element, and the star stops producing energy.

The most massive stars reach the end of this cycle in only a few million years. When these stars run out of elements that can be fused, the force of gravity finally overwhelms the outward push from the energy generated by the fusion. As a result, the core of the star collapses catastrophically and releases enough energy to blow apart the rest of the star. These "supernova explosions" are so bright that they briefly outshine entire galaxies! Supernovae (the plural of supernova) also have so much energy that iron can be fused into heavier elements during these explosions. In addition, all the elements that were formed inside the stars are spewed out when they explode, and elements are dispersed throughout the Universe.

We know the Sun is a later-generation star because even though it is still only fusing hydrogen, it contains those heavier elements that can only be formed inside massive stars and distributed by supernovae (we know that from spectroscopy, among other ways). Since the Big Bang only produced hydrogen and helium, most of the elements in our bodies - like carbon, hydrogen, nitrogen, oxygen, and trace amounts of many others – must have come from the explosion of earlier stars! We are all literally made of star stuff!

After the supernova, only the core of the massive star is left behind, which will then turn into either a neutron star or a black hole. A neutron star is an extremely dense star whose gravity is so strong that protons and electrons combine to form neutrons. The density in the interior of a neutron star is much higher than in the interior of a white dwarf — a sugar-cube sized lump of neutron star material would weigh 100 million tons on Earth!

If the star is particularly massive (heavier than about 3 times the mass of our sun), the stellar core that's left after the explosion is still too massive to support itself against gravity. Therefore, it continues to collapse until it forms a black hole, which is a point in space with tremendous gravity – so great that not even light can escape from it, hence the term "black" hole. We will explore black holes more in the session called "Black Holes in Orbit."

Preparation

1. Make sure you have ice made up ahead of time. Although this activity can work without ice as long as you have very cold water, it is easier with ice water.

2. It is a good idea to practice the imploding can trick (ideally with the same tools you will have during the session) before you are called upon to perform in front of students. Make sure that you can see plenty of steam from the can and can hear it bubbling before inverting it onto the water. This can be a temperamental demonstration, and practice helps a lot.

3. Also, it may take a while for the water in the can to boil, so it's a good idea to start it heating before starting the activity, or have a helper set it up ~15 minutes before you get to that part of the activity. (Actual heating times will vary depending on your hotplate.)

Activity

Review: Elements

As the activity begins, ask the students what they have learned about elements in the universe (if they have already participated in the Elements and You activity) or what they know about elements (if they have not participated in the Elements and You activity). Remind them that the elements of which they are made (carbon and oxygen, for instance) are very rare in the Universe and are made in stars. They should know that the stuff created inside stars needs to get out somehow (in a big explosion). Try to ask them questions and unearth any possible misconceptions before the rest of the activity begins. What is an element? What are different kinds of elements? What is an atom? What is an atom made of?

In this activity, we are going to figure out how to make a star EXPLODE in order to distribute different elements into the universe! Not all stars will become supernovae, so first we need to understand the life cycle of stars.

Talking Point: Forces in a Star

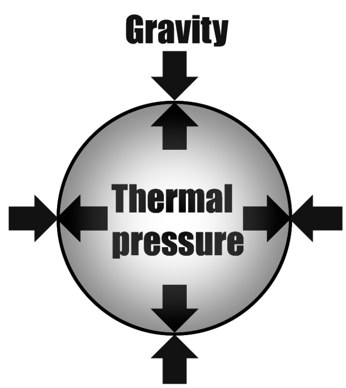
How do different sized stars behave and how do they age?

Ask the students about what they know about forces. What is a force? What kinds of forces do they know about?

A key concept to reinforce is that there are different types of forces at work in a star – two of these are gravity, which holds objects and materials together, and pressure from hot material and fusion, which fights the gravity and pushes outward.

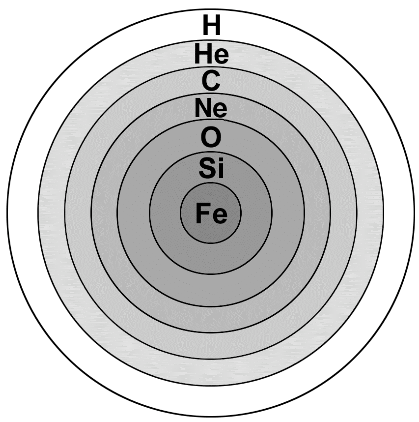
All stars fight gravity by releasing large amounts of energy through fusion. Remember that fusion is the process stars use to create different types of elements. Lighter atoms join together to create heavier atoms and release energy. This is a complicated process, but we can think of it simply. Remind them of the demonstration with clay balls from the morning's Elements and You activity.

The more mass that a star has, the hotter it can get in its core, and the more it can use energy from fusion to support itself from collapse, because the pressure from the fusion energy pushes outward against the gravitational pressure pushing inward. The key here is that these forces are in balance through most of the star's life.



Demonstrate this balance by having two volunteers come up and face each other. If they press their hands against each other with the same force, nothing happens.

Bigger stars can fuse heavier and heavier elements. This process stops with iron (Fe), if you remember from the Elements and You activity. This process creates layers of different elements like an onion.



(It is helpful to have the model star to refresh their memories.) We'll talk about iron more in a few minutes.

1. **What happens at the end of Fusion?**
   Ultimately, all stars will loose the ability to fuse elements, because they run out of elements that they can fuse. At this point, the core may be dense enough to support itself – the gravity pushing down is not strong enough to crush the core. (The following description (adapted from http://www.adlerplanetarium.org/) demonstrates at what stage a star looses this ability to fuse elements and whether the star is light enough to support itself by other means.)

2. **So, what are the different kinds of stars, and what happens to them?**
   Now, we'll look at how a star changes over time (or evolves) depending on its mass. Ask the students whether they think the most massive stars will be the hottest or the coolest. (Answer: hottest.) Ask them what colors of light come from the hottest and the coolest things. (Answer:

hottest stars are bluer and cooler ones are redder – they may or may not come up with this response.) Have six students blow up balloons according to the following table.

Activity: Stellar Life Cycle (approximately 10 minutes)

Main Sequence Star Masses, Balloon Diameters, and Balloon Colors

Spectral Class	Relative Mass	Balloon Color	Relative Radius	Balloon Diameter	Comments:
O	23	Violet	7.4	19 in	Fuse → Fe – run out of fuel
B	8	Blue	4.3	10.5 in	Supernova → Black Hole
A, F	1.6	Green	1.4	4 in	Supernova → Neutron Star
G (SUN)	1	Yellow	1	2.5 in	Fuse → O – stable "white dwarf"
K	0.8	Orange	0.8	2 in	
M	0.4	Red	0.6	1.5 in	Fuse → H, He – stable, cool

Please note, this is a table of Main Sequence (ordinary stars that shine because of fusion) – NOT an evolutionary progression.

A common way to remember the spectral types (OBAFGKM) in order is with the pneumonic, "oh be a fine girl, kiss me." Some students may recognize this pneumonic.

Red/Orange Stars: These are very cool stars. They can fuse hydrogen into helium, but not much else. The helium in the core won't get hot enough to fuse together. The star will cool off and become fairly useless. The same kind of pressure that keeps us from sinking into the ground due to gravity will hold up the star against gravity until the end of time.

Yellow/Green Stars: These stars are similar to our Sun. They can fuse hydrogen into helium. It can also get hot enough to fuse the helium in carbon and oxygen, also lithium, boron, and beryllium. But, that's all. The star can't get hot enough to fuse carbon or oxygen into heavier elements, but the star is light enough that the dense carbon/oxygen core can support the star. This is called a white dwarf. No supernova here.

Blue/Violet Stars: Now we are getting somewhere! This is a really hot and really massive star, and it can do all the things the other stars can do and more! Fusion of elements will continue until the core is iron. But here, we run into two problems: (Ask students what these might be.)

i. Iron can't fuse into anything else (they should have learned this in the Elements and You activity).
ii. The star is too massive to be supported by the iron core in the same way the other stars are.

So we've reached a breaking point. The iron core is going to get hotter and hotter and hotter until, through a complicated process, the iron atoms come apart into the smaller components. This leads into the next activity.

Demonstration: Implosion (approximately 10 minutes)
(adapted from http://chandra.harvard.edu/graphics/edu/formal/demos/contraction.pdf)

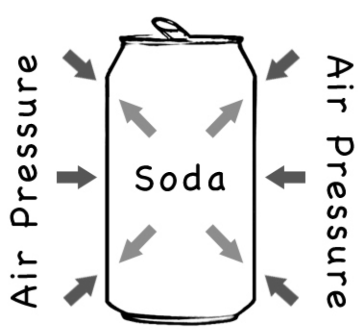
The core of the blue/violet star now has no way supporting itself against gravity. Tell the students that we will now explore what happens inside the star when the fusion stops.

Warning: Make sure students don't get too close to this one! The hot plate remains hot for most of this session!

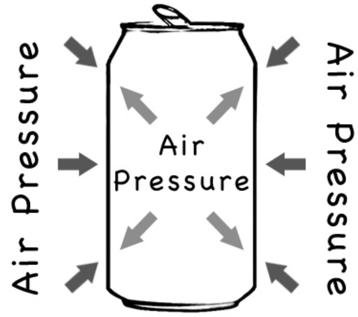
Place a small amount of water in an empty aluminum soda can (about 1-2 tablespoons). Too much water will cause this demonstration to not work. Set the cans on the hot plate. Heat the can until the water starts to boil. When plenty of steam starts to come out of the opening in the top of the can, pick up the can with an oven mitt or tongs and quickly flip it over (open side down) into a bowl of cold water. The can will instantly implode with a crunching sound.

Why does this happen, and how does it relate to our massive star?

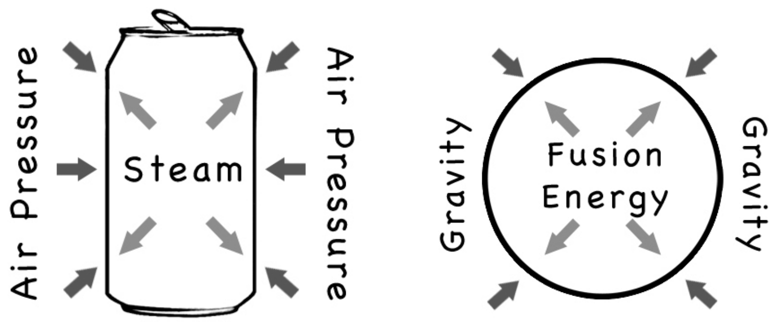
When you buy the aluminum can from the store and it still has liquid in it, the can holds its shape due to the equilibrium between the pressure from the soda inside directed outward and the pressure of the air outside of the can directed inward.



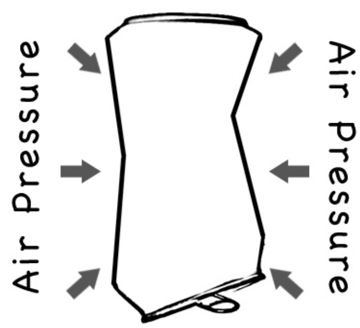
After the can has been emptied of liquid, the shape is held in equilibrium by the pressure of the air inside the can directed outward and the pressure of the air outside of the can directed inward.



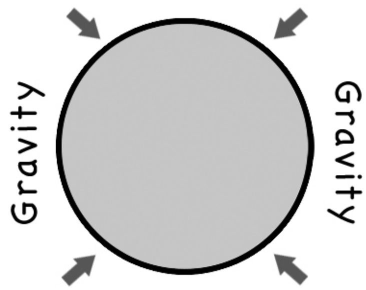
Heating the water in the can causes it to turn into steam, which drives the air out of the can because the steam has higher pressure. Now the can is held in equilibrium by the pressure of the steam pushing outwards (analogous to the radiation pressure in the core of the star) and the pressure of the outside air directed inwards (analogous to the gravity of the star directed inwards).



When the can is inverted over the cold water, the steam instantly condenses into water. The water occupies a much smaller volume than the steam did, resulting in much less pressure inside the can. With nothing on the inside to balance the outside pressure the can will implode (like the core of a star collapsing).



This is sort of like what happens in a supernova, the end of the line for large stars. The star collapses when the two forces that were balancing each other – pressure outwards from the energy generated at the center countering the force of gravity inwards – are no longer in equilibrium.



The central core of the star collapses (similar to the implosion of the can) and the material in the rest of the star starts to fall onto this core. It rebounds and sends the material in the star flying out. This is what is called a supernova explosion and the power of this rebound effect can be seen in the next demonstration. Supernovae do a very important job in the Universe – the explosion sends all those elements out into space and makes new elements with its energy.

Demonstration: Getting from an Implosion to an Explosion (approximately 5 minutes)

Discuss the difference between an *implosion* (falling inward) and *explosion* (going outward). We saw that the can imploded because the pressure inside the can disappeared. But when we think of a supernova, we think of an explosion. So how do we get from an implosion to an explosion?

Show the students the Hoberman sphere. We can use this sphere to answer our question. You can invite a student up to do this demonstration if you would like.

Open the sphere all the way, and then let it collapse under its own gravity. Try to do this so that it is still falling when it collapses all the way (in other words, while it is still in the air rather than on the ground).

What happened when the sphere reaches the end of its collapse? You should be able to observe a "bounce" at the end when all of the parts falling towards each other rebound off of each other. This can be difficult to see, so you probably want to show them the collapse and bounce a few times. This is how we turn an implosion into an explosion.

Activity: Atmosphere Ejection (approximately 10 minutes)
(adapted from http://chandra.harvard.edu/graphics/edu/formal/demos/ejection.pdf)

Now let's take a look at the supernova explosion itself.

Give students a pair of differently sized balls. Have as many students as possible participate, within the limits of your supplies. Have these students stand in a group.

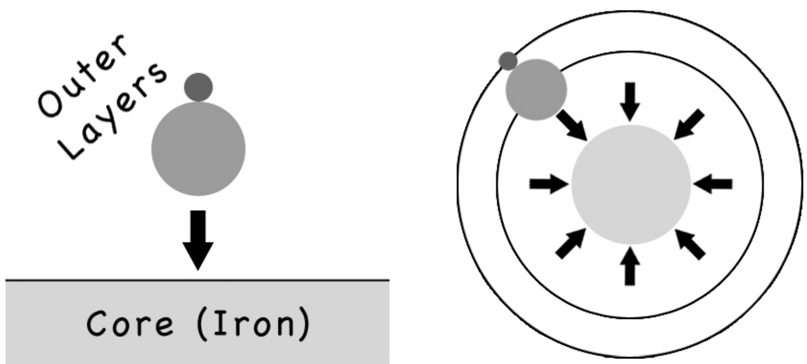
Ask the students to predict how high each ball will bounce when dropped (not thrown at the ground, just gently dropped). Once the students have made their predictions, let them try it.

Now ask the students to predict how high the balls will bounce if they are dropped with the smaller ball stacked on top of the larger one, as pictured below.

Have everyone yell "3-2-1-SUPERNOVA!" and drop their stacked balls at once. What happened? Assuming the two balls fell together, the smaller ball should suddenly rebound with a lot of energy. It will bounce higher than it did when it was dropped by itself – potentially much higher – while the larger ball doesn't bounce much at all. Do this activity several times so that everybody has a chance to do this activity at least once.

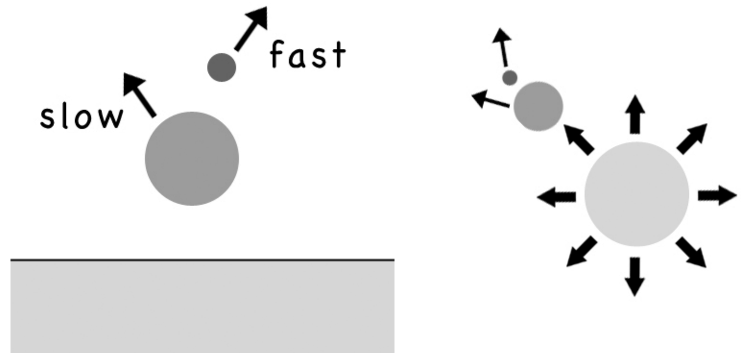
So why does this happen? In this situation, the smaller ball absorbs the energy of the larger ball. Since it is so much smaller, that energy is capable of doing a lot more, and the ball bounces much higher than it did before.

So how does this relate to our supernova explosion? In this experiment, the ground (Earth) represents the dense inner core of a star. The larger ball represents the outer part of the core that is falling inward as the star collapses. The smaller ball represents the outer layers – or atmosphere – of the star. This comparison is illustrated in the following images.



Illustrations of the balls in this activity as the layers of a star falling towards the iron core as it goes supernova.

We saw earlier what happens to turn our star's collapse into an explosion. The bounce we witnessed with the Hoberman sphere is what we are looking at now in more detail. Our two balls hit the floor, and the smaller one rebounds with a lot of energy, just like the outer layers of our star. This idea is again illustrated in the following images.



Illustrations of the tennis and ping pong balls as the outer layers of a star shooting off into space after it has rebounded off of the iron core during a supernova explosion.

Now have the students imagine what it would be like if everyone on Earth did this experiment at the same time. With the idea of 6 billion balls shooting off in all directions from the Earth at the exact same time, we start to get a more accurate mental image of a supernova.

Talking Points: Wrap-up (approximately 5 minutes)

Discuss with the students the following key concepts that we learned in this activity to check for comprehension.

- ★ Not all stars will end their lives in a spectacular supernova. Without help, only the ones that are massive enough to try and fuse iron will do so.
- ★ Every star is fighting against gravity. They start doing this using the energy released by fusing hydrogen into helium. Some stars will only get this far and will only have the structure of the matter itself fight gravity with.
- ★ Other stars can get hot enough to fuse helium, etc. The hottest/most massive stars will get to the point where they have an iron core, but this is a problem because iron doesn't fuse and stars are too massive to be supported any other way.
- ★ With the loss of material to fuse (because iron cannot be fused), we lose our initial balance, and the star implodes (collapses inward). Stuff in the core and bottom of the atmosphere will "bounce" when it meets other stuff falling in from the other side. This bounce will cause the outer layers of the atmosphere to violently explode (fly outward). In the remaining core, the neutrons might be able to hold up what's left. This is what's called a neutron star. If the remainder of the core is too massive even for neutrons, it will become a black hol0e.

Black Holes in Orbit

Summary

Students are introduced to the basic properties, behavior and detection of black holes through a brief discussion of common conceptions of black holes and how black holes might be detected through their interaction with other objects. Then they "act out" this detection process by representing binary star systems in pairs, walking slowly around one another in a darkened room with each pair holding loops of wire to simulate the gravitational interaction. Most of the students are wearing glow-in-the-dark headbands to simulate stars, some are without headbands to represent black holes, and a small set of the black holes have flashlights to simulate X-ray emission.

Objectives

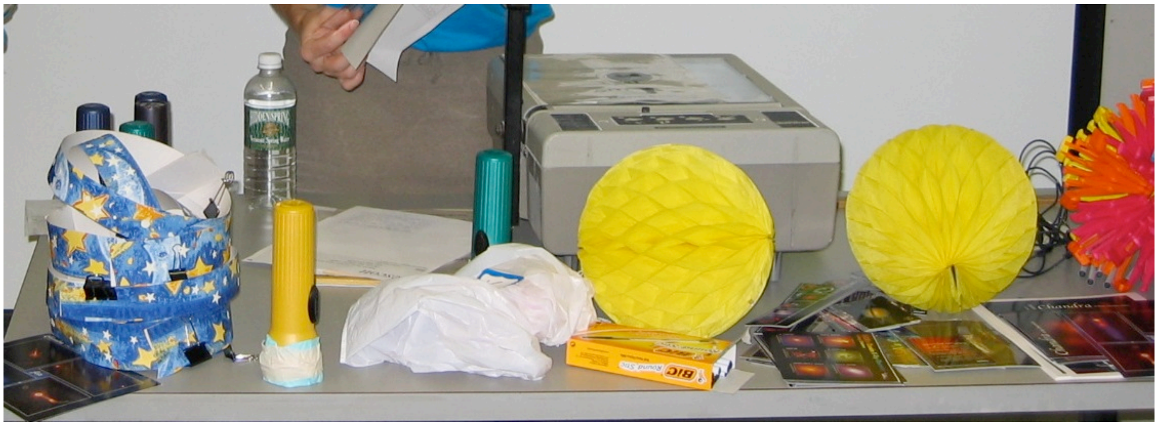
- To learn the basic properties of black holes, including:
    - Escape velocity
    - Gravitational interactions
    - Accretion disks
- To consider black holes less mystifying
- To brainstorm ways to observe objects or phenomena which cannot be seen directly
- To be introduced to basic X-ray physics

Materials

- Tennis ball
- Set of density blocks (objects of the same size and different weights) *
- Loops of heavy gauge wire, ~ 36 inches in circumference (5-6)
- Loops of heavy gauge wire, ~ 60 inches in circumference (5-6)
- Glow-stick necklaces (one per student) **
- Flashlights and batteries (6)
- Cellophane or tissue paper to cover flashlight lenses
- Tissue paper party decorations – 2 large (~ 8 inch diameter) balls, 1 large (~ 24 inch diameter) disk

** Information about where to purchase this can be found in Appendix B.*

*** In the past, we have used headbands with glow-in-the-dark stars on them. They had the advantage of being cheap and reusable, but proved difficult to see unless the room was 100% dark. This prompted us to switch to glow-stick necklaces. There is certainly room here for substitutions to be made, but the key is to have something light emitting that can be seen no matter which direction the student is facing (such as a necklace, a headband, or a belt).*

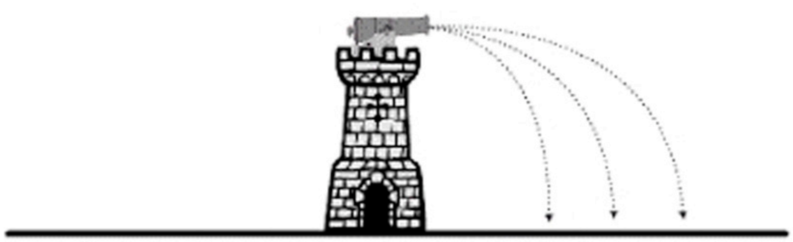


Other Requirements

- ★ A room with adequate space to move around for the activity
- ★ A room that can be darkened (preferably completely darkened)

Background

On Earth, when you throw a ball into the air, it falls back to the ground because the Earth's gravity pulls the ball back down. The higher and faster you throw it, the longer it will take to fall back to the ground. The same principle applies to the cannon balls in the following image. The faster the cannon balls are shot, the farther they will go.



Faster cannon balls getting farther as they are shot off a tower.

If you could throw the ball with enough speed, it would not come back down, but would continue around the planet (in orbit.)

Illustration showing that if a cannon ball were
shot fast enough, it would go around the Earth.

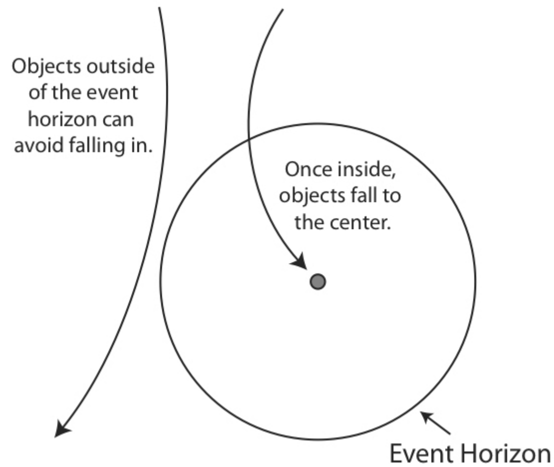
For each body in the Universe there is a certain speed at which an object must travel in order to escape the body's gravitational pull. This special speed is called the "escape velocity," and it differs for each body depending on its mass. Any object traveling slower than the escape velocity will fall back to the surface, but any object traveling faster will continue moving away from the body. The reason we are able to send rockets into space is because they are accelerated to speeds greater than Earth's escape velocity. On Earth, this speed is 11.1 kilometers per second (or 40,200 kilometers per hour), which is the same as 7 miles per second (or 25,000 miles per hour). Other objects have different escape velocities, depending on their mass – the more massive something is, the higher the escape velocity from that object will be. For example, the moon is less massive than the Earth, and so its escape velocity is only 2.4 kilometers per second (1.5 miles per second). Moreover, the Sun, which is much more massive than the Earth, has an escape velocity of 621 kilometers per second (386 miles per second), forcing objects to travel at much higher velocities in order to escape its gravity.

Black holes are such dense objects, with such an incredibly strong gravitational pull, that their escape velocity exceeds the speed of light! Since Einstein showed that nothing can travel faster than light, then nothing can escape the gravity of black holes, not even light!

There is strong observational evidence for two types of black holes – stellar mass black holes, which are typically 5-15 times as massive as our Sun and are formed when large stars explode as supernovae and collapse; and supermassive black holes that are millions to billions times the mass of our Sun and are always found at the centers of galaxies. For example, our own galaxy, the Milky Way Galaxy, has a central supermassive black hole that is 3 million times the mass of our Sun, but only about the size of our solar system. The formation of these supermassive black holes is still mysterious and the subject of a great deal of current research.

A third type of black hole, known as an intermediate mass black hole, is also thought to exist. These black holes are predicted to weigh about 1000 times the mass of our Sun and are an active area of research.

The event horizon of a black hole is the spherical boundary between the black hole and the outside universe, within which any object (or even any light ray) would have to exceed the impossibly high escape velocity to avoid falling inwards towards the center of the black hole. It is the 'point of no return' in the sense that that once any object strays inside of the event horizon, it will never be able to escape the black hole's gravity, and will fall into the very center of the black hole. In this region the infalling matter is destroyed and our current laws of physics probably become invalid.



The gravitation effect of black holes.

It is important to realize that outside of the event horizon a black hole exerts the same gravitational force on nearby objects as any other object of the same mass would. For example, if the Sun were magically crushed until it had a radius of only 3.2 kilometers (2 miles), it would become a black hole, but the Earth would feel the same gravitational force and hence remain in the same orbit as before the Sun was crushed. In this sense, black holes are not cosmic vacuum cleaners that reach out and suck everything into them. Thankfully, our Sun is not big enough to ever become a black hole, so don't worry about that!

Not surprisingly, black holes can be very challenging objects to detect as space is also black! Astronomers cannot observe black holes directly, but instead detect them through their gravitational effect on nearby gas and stars. A particularly important example is when a normal star (like the Sun) is orbiting a stellar-mass black hole. In this case, the gravity of the black hole can pull gas off the surface of the star and into itself. As the gas spirals into the black hole, it gets extremely hot and emits a large amount of X-rays, which modern X-ray telescopes can detect. Observations can also reveal how the normal star "wobbles" as it orbits around the unseen black hole, and so reveals the black holes presence.

Preparation

1. Wire loops: approximately 10 minutes
   Cut and shape the wire into 5-6 medium sized loops (approximately 36 inches in circumference) and 5-6 large loops (approximately 60 inches in circumference). Make a figure 8 shape with both loop sizes, attaching two of the same size together. The students will use this to simulate the gravitational pull at different distances between stars and black holes.

2. Flashlights: approximately 5 minutes
   Cover the lenses of the flashlights with cellophane or tissue paper, and tape this into place.

3. Darken the room: variable
   The room should be capable of going from brightly lit to dark so that the glow stick necklaces can be seen effectively. Sometimes this means lights or light leaks must be covered. Dark black plastic trash bags and duct tape have proved useful for this.

Activity

Talking Point: Initial Ideas about Black Holes

Ask the girls what they know about black holes. Allow them to brainstorm their ideas.

If it doesn't come up on its own, ask if they know why we call them black holes. They will probably say it is because they are black, but why are black holes black?

If black holes are black and space is black, how do we find them?

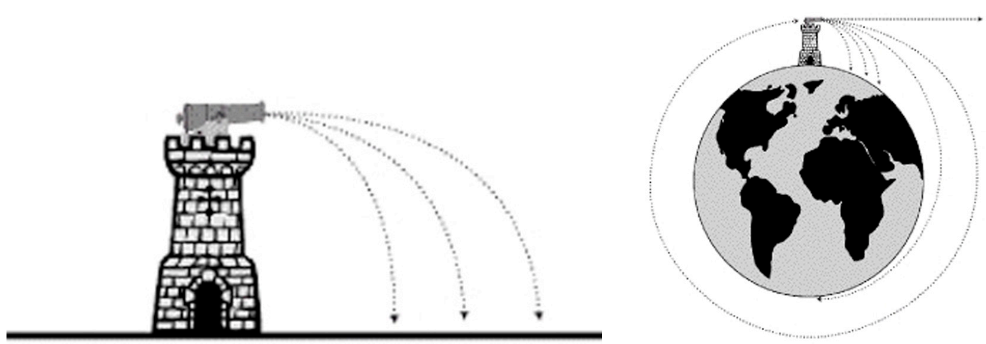
Tell them that we will be exploring these questions.

Talking Point: Orbits

If an object orbits another object, it goes around that object in a fairly fixed circle or oval. The Moon orbits the Earth, the Earth and other planets orbit the Sun, and sometimes two stars orbit each other. When this happens, we call them binary stars. Roughly half of the stars visible in the sky are binary stars, so this is relatively common. You can demonstrate the idea of an orbit using the two round party decorations (or any other round objects) and showing them going around each other.

Demonstration: Escape Velocity

Use the example of a tennis ball to help explain this concept. If you toss a tennis ball in the air, it falls back down to the ground. Ask them if they know why – the answer is gravity. If you toss the ball a little bit harder and faster, it takes a bit longer to fall back down to the ground. Theoretically, if you could toss this tennis ball hard enough and fast enough, it would not fall back down. The illustration below of a cannonball being shot from a tower also illustrates this idea. As the cannonball is shot with more speed and force, it goes farther and farther. Eventually, with enough speed and force, the cannonball goes into orbit, and with even more force, the cannonball escapes entirely.



The minimum speed that anything must be going in order to escape an object's pull is known as the escape velocity, and it varies depending on the mass of the object. The speed you would have to throw the tennis ball on the Moon is less than the speed you would have to throw it on the Earth because the Moon is smaller and less massive than the Earth. Likewise, the escape velocity for the Sun is much greater than the escape velocity for the Earth because the Sun is much more massive than Earth.

Demonstration: Density

Ask if the students know what the word "density" means. Most likely they will have some idea. Density is a physical property that can be related to an object's size and mass/weight. Ask them to think of examples of everyday objects that are very small and heavy (high density) or large and light (low density).

You can also pass around the element/density cubes or ask for volunteers to come to the front to handle them. These cubes are all exactly the same size, but since they are made out of different materials with different physical properties, they have different weights. This is an example of density.

Talking Point: What is a BH?

A black hole is an object so massive that the escape velocity is greater than the speed of light. This means that nothing, not even light, which is the fastest thing in the universe, can ever escape from inside a black hole. The fact that no light can escape from these objects is why we call them *black* holes.

Black holes are also very small in size. Combined with their high mass, this means that black holes are incredibly dense. In fact, they are the densest things that we know about in the universe.

Talking Point: Observing a BH

If not even light can escape a black hole, then how can we know they're there? After all, space looks black as well. The primary way that we observe black holes is by the effects of gravity. If a star in a binary star system becomes a black hole, it will still have another star orbiting around it. When we observe such a star apparently orbiting around nothing that can be seen, we can assume that there is a black hole there. We will be doing an activity to demonstrate this idea.

Activity: Detecting Black Holes (approximately 15 minutes)

In this activity, students will play the part of stars and black holes, and observe how astronomers might be able to detect these objects, even though no light escapes from them. The numbers below assume a group of 25. You should adjust the numbers accordingly for the size of group and the space that you have.

It might be worthwhile to have some of the students on the sidelines as observers, and then have them switch with the participants, to give everybody a chance to both observe and act out a role. It is also useful to have a helper stationed by the light switch who can make the room go dark at will.

1. Demonstrate an orbit for the purposes of this activity by having two volunteers hold onto opposite ends of a figure-eight wire, pull it apart, and circle around each other.

2. Have 16 of the students wear glow stick necklaces. These students are "stars." The rest of the students will not wear the necklaces, and will therefore be invisible in the dark; they will be the "black holes."

3. Divide the students up roughly as follows:

   3 of the students will be normal stars, without a pair, moving through the galaxy. 5 pairs of students will be normal binary star pairs orbiting around each other. 5 of the students with necklaces will pair with 5 students without necklaces to be normal star

& black hole binary pairs. The remaining 2 students without necklaces will be black holes without a pair.

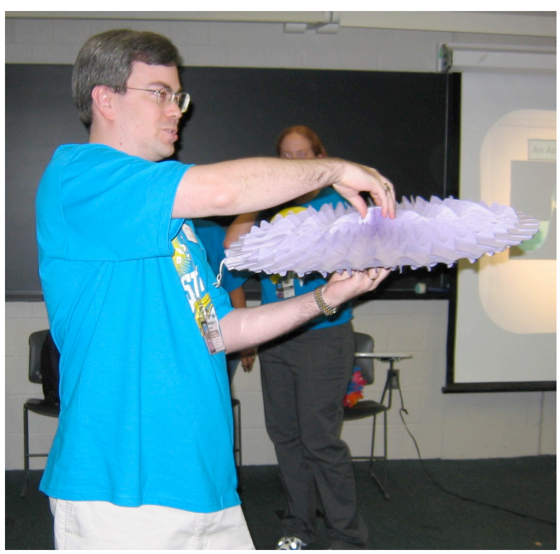
4. Each pair (whether a pair of normal stars, or a star and black hole pair) should be given a figure-eight wire. These wires come in different sizes to represent differences in how closely objects orbit each other.

5. Explain that the lights will be turned off and each pair of students will orbit each other. The unpaired students will be scattered around the room on their own. Make sure you tell all the students to circle or move slowly so as to avoid injuries. Practice the activity once with the lights on.

6. Turn the lights off and run through the activity. Have the students observe what happens. They will be able to see the stars because the glow stick necklaces give off light. The black holes, however, will be invisible (this is most dramatic when you can fully darken the room). Whenever a black hole is paired with a normal star, they will be able to see the star going around something, but they will not be able to see what. If two black holes are paired together, nothing will be visible. This is what happens with black holes in space.

Talking Point: Accretion disks

Though black holes are not cosmic vacuum cleaners that wander around the universe sucking things up, their gravitational pull does cause nearby material to be pulled in. This effect is most pronounced when the black hole is orbited by another star. As material spirals in towards the black hole, a disk is formed. [You can use the tissue paper disk and ball to illustrate an accretion disk and an orbiting star.] The materials in this disk interact with each other, and as they do, friction causes them to become very, very hot. This causes light to be emitted, usually in the form of x-rays. Since this light is generated by material *around* the black hole, rather than within the black hole, this light can escape, and we can detect it, giving us another way of detecting a black hole. At the end of this session there is an image of an artist's conception of an accreting black hole that can help with student visualization of an accretion disk.



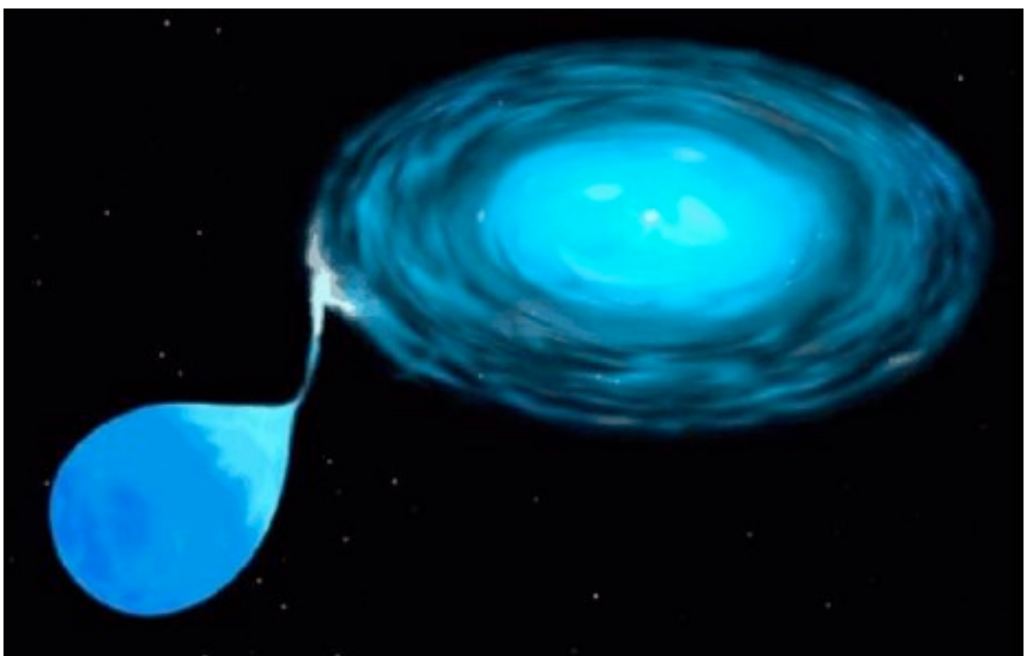
Activity: Detecting Black Holes with X-Rays (5-10 minutes)

In this activity, students will play the part of stars and black holes, and observe how astronomers might be able to detect these objects, even though no light escapes from them. The numbers below assume a group of 25. You should adjust the numbers accordingly for the size of group and the space that you have.

It might be worthwhile to have some of the students on the sidelines as observers, and then have them switch with the participants, to give everybody a chance to both observe and act out a role. It is also useful to have a helper stationed by the light switch who can make the room go dark at will.

1. Any black holes who are paired with a star using the smaller sized figure-eight wire should be given one of the flashlights. One of the unpaired black holes should also be given a flashlight.

2. Turn the lights off and run through the activity once again. This time have the students with flashlights turn them on. Everybody should now be able to detect the x-rays emitted by the accretion disks around some black holes. The idea here is that with the closer binary systems, the star and black hole are close enough for accretion to take place, i.e. the star "donates" some of its mass to the black hole and X-rays are emitted. This demonstrates a second way that scientists can detect black holes.



Talking Point: Wrap-up

Ask them questions based on this activity. Probe whether they now understand what a black hole is and how we detect them. While the leader does this, the helpers should go around and collect the flashlights and wire loops used in the activity.

Materials Checklist

This checklist will help you assemble and review your supplies for each session. Quantities of each item are not listed, as that will be determined by the size of your group. Additional details about the materials needed are available in the session write-ups.

Elements and You

❒ Plain pound cake
❒ Knife (for cutting pound cake)
❒ Napkins or paper plates (for serving pound cake)
❒ Gloves or wet wipes (for safe food handling)
❒ Example(s) of pure elements (sheet of aluminum, copper tubing, elemental density cubes, etc.)
❒ Large periodic table to display
❒ Periodic table handouts
❒ Large mixing bowl
❒ Pony beads (clear, light blue, dark blue, black, green, orange, pink, purple, red, and yellow)
❒ Small scoops or Dixie cups
❒ Universe of Beads key
❒ Universe of Beads worksheets
❒ White rice
❒ Brown rice
❒ Split peas
❒ Black beans
❒ White beans
❒ Pinto beans
❒ Red beans
❒ Red lentils
❒ Brown lentils
❒ 8 oz plastic bottles with lids
❒ Tape for sealing bottles
❒ Funnel
❒ Bottle key
❒ Red modelling clay
❒ Yellow modelling clay
❒ Orange modelling clay
❒ Green modelling clay
❒ Blue modelling clay
❒ Trash can or trash bag
❒ White board, easel pad, or overhead projector (optional)

Rainbow Analysis

❒ Paper towel tubes
❒ Aluminum foil
❒ Diffraction grating
❒ Masking tape
❒ Ziploc bags for spectroscope kits (optional)
❒ Poster or handout about the electromagnetic spectrum
❒ Example spectrum handout
❒ Incandescent light bulb
❒ Discharge lamps (optional)
❒ Completely blacked-out room (optional)

Supernova Explosion

❒ Colored balloons (red, orange, yellow, green, blue, violet)
❒ Empty soda cans
❒ Hot plate (or Bunsen burner and screen/ring setup)
❒ Large bowl
❒ Cold water
❒ Ice
❒ Tongs or oven mitts
❒ Hoberman sphere
❒ Basketballs (or kickballs, soccer balls, etc)
❒ Tennis balls
❒ Model clay ball from Elements and You session (optional)

Black Holes in Orbit

❒ Tennis ball
❒ Set of density blocks (objects of the same size and different weights)
❒ Loops of heavy gauge wire, ~ 36 inches in circumference
❒ Loops of heavy gauge wire, ~ 60 inches in circumference
❒ Glow stick necklaces
❒ Flashlights with batteries
❒ Cellophane or tissue paper to cover flashlight lenses
❒ Tissue paper party decorations
❒ Room with adequate space to move around
❒ Completely blacked-out room (optional)

Shopping Suggestions

The activities in *Big Explosions and Strong Gravity* are designed to utilize readily accessible materials – most items can be purchased at a supermarket, mass merchandiser, or craft store. A few items are exclusively available through specialized suppliers, and this section provides detailed information about purchasing. This should be taken as suggestion only, and by no means as an exhaustive list.

Elements and You

This session uses examples of pure elements to guide student discussion about what an element is and what the differences between elements are. The simplest way to do this is to buy one of the science density kits that are out there and include cubes or cylinders of the same size made out of different metals (or alternately of the same mass and therefore different size, but having one of these remain constant will help with the comparison). Try to limit yourself to kits that use primarily elemental materials (not wood, plastic, etc).

- Uniscience Laboratories (http://www.unisciencelab.com/) has several options that will work, with only the inclusion of brass as a non-element (look under Mechanics and then Cubes and Cylinders).

    - Metal Cubes
        - 10 mm sides
            - 3510-01: Set of 6
            - 3510-11: Aluminum
            - 3510-13: Copper
            - 3510-14: Iron
            - 3510-15: Lead
            - 3510-16: Zinc
        - 20 mm sides
            - 3510-02: Set of 6
            - 3510-21: Aluminum
            - 3510-23: Copper
            - 3510-24: Iron
            - 3510-25: Lead
            - 3510-26: Zinc
        - 25 mm sides
            - 3510-03: Set of 6
        - 32 mm sides
            - 3510-04: Set of 6
            - 3520-01: Aluminum (with hook)
            - 3520-03: Iron (with hook)
            - 3520-04: Lead (with hook)
            - 3520-05: Copper (with hook)
            - 3520-06: Zinc (with hook)

    - Cylinders
        - 3525-01: Set of six 10 x 30 mm cylinders
        - 3525-02: Set of six 10 x 40 mm cylinders

- ♣ Educational Innovations (http://www.teachersource.com/)
  - ♦ DEN-220: Set of 6 (aluminum, brass, copper, iron, lead, and zinc) 25 mm cubes

- ♣ Science Kit and Boreal Laboratories (http://sciencekit.com/) has a set of equal mass (but not equal size) cubes in copper, aluminum, zinc, iron and brass.
  - ♦ Item #: WW4800900

Rainbow Analysis

This session requires single-axis diffraction grating, a thin plastic film that will allow the light to be broken up into its component parts. This can be purchased from various science supply stores online. Some options are listed below, but a quick search online will turn up other options. Remember to purchase at least 1 square inch per spectroscope.

- ♣ Educational Innovations (http://www.teachersource.com/)
  - ♦ PG-400: Single Axis Diffraction Grating (6" x 24" sheet)

- ♣ Edmund Scientific (http://www.scientificsonline.com/)
  - ♦ Item #3052116: Diffraction Grating Film (200' x 6" sheet)

- ♣ Rainbow Symphony (http://www.rainbowsymphonystore.com/)
  - ♦ Item #01505: Diffraction Grating Film Sheet – 500 lines per mm (6" x 12" sheet)

This session also uses Element Discharge Lamps. If you plan to use these, you will need to purchase both the lamp bases and the individual element bulbs. While there are many different options for element tubes, I have only included a few options below. You will want a few different examples to compare, if possible.

- ♣ Edmund Scientific (http://www.scientificsonline.com/)
  - ♦ Item #3071559: 115V Power Supply
  - ♦ Item #3060906: Hydrogen Spectrum Tube
  - ♦ Item #3060907: Helium Spectrum Tube
  - ♦ Item #3060912: Oxygen Spectrum Tube
  - ♦ Item #3060911: Nitrogen Spectrum Tube
  - ♦ Item #3060910: Neon Spectrum Tube
  - ♦ Item #3060914: Carbon Dioxide Spectrum Tube
  - ♦ Item #3060913: Water Vapor Spectrum Tube

Supernova Explosions

This activity uses a Hoberman sphere, which can be purchased various toy stores. They come in multiple colors and sizes. Information about one option for purchasing them online is included here.

- ♣ Toy and Game Warehouse (http://www.toyandgamewarehouse.com/)
  - ♦ HS115: Hoberman Sphere Spectrum
  - ♦ HS104: Hoberman Rainbow Sphere
  - ♦ M1301: Hoberman Mini Sphere Rainbow

- ♦ HS124: Hoberman Sphere Rings
- ♦ M1335: Hoberman Mini Sphere Rings
- ♦ HS119: Hoberman Expanding Universe Glow Sphere
- ♦ M1319: Hoberman Mini Expanding Universe Glow Sphere
- ♦ HS105: Hoberman Firefly Glow Sphere
- ♦ M1336: Hoberman Mini Firefly Glow Sphere

Periodic Tables

While there are many different places to get poster-sized periodic tables, we have been particularly fond of the following option because it shows examples of different elements in their place on the table. Please feel free to use whatever you might prefer.

- ♣ Edmund Scientific (http://www.scientificsonline.com/)
  - ♦ Item #3053432: Laminated Periodic Table
  - ♦ Item #3053431: Periodic Table on Sturdy Paper

Smaller periodic tables that can be used for handouts are also available from many different sources. You can print copies of the periodic table in this manual for free, but if you choose to purchase period tables, here are some options.

- ♣ Schoolmasters Science (http://www.schoolmasters.com/)
  - o Item #15027: Pad of 100 Notebook Size Periodic Tables

- ♣ Science Kit and Boreal Laboratories (http://sciencekit.com/)
  - o WW61057M00: Pad of 100 Notebook Size Periodic Tables

Astronomy Resources

Astronomy News and Get Involved

- NASA: NASA's website helps you to stay up to date with everything NASA, including news, research, images, videos, and more. (http://www.nasa.gov/)
- Blueshift: As NASA Goddard's Astrophysics Division Education and Public Outreach website, Blueshift "brings the universe closer to you" with blogs and podcasts about life at Goddard and news from around the astronomy world. (http://astrophysics.gsfc.nasa.gov/outreach/podcast/wordpress/)
- APOD: The Astronomy Picture of the Day posts a new astronomy picture daily along with a short description written by astronomers. (http://apod.gsfc.nasa.gov/apod/astropix.html)
- Astronomy Cast: Astronomy Cast is a weekly podcast with nearly 200 past episodes containing a wealth of astronomy information. (http://www.astronomycast.com/)
- Astronomy Clubs: Find an amateur astronomy club near you and get involved. (http://www.AstronomyClubs.com/)
- Radio Jove: NASA's Radio Jove project provides low cost radio telescopes to allow students and teachers around the world to participate in astronomy research. (http://radiojove.gsfc.nasa.gov/)
- Google Sky: Google Sky enables you to scan the night sky and learn about constellations, the solar system, galaxies and more. (http://www.google.com/sky/)
- Space.com: Space.com keeps you up to date on astronomy, science and techonology news. (http://www.space.com/)

Student Resources

- NASA for Students: NASA's student website contains NASA news, opportunities to get involved and more. (http://www.nasa.gov/audience/forstudents/index.html)
- Imagine the Universe: Imagine the Universe is meant for students age 14 and up to explore astronomy and the work NASA is doing. (http://imagine.gsfc.nasa.gov/)
- STEM Careers: Learn about all the different STEM careers and what to do now to get there. (http://stemcareer.com/)
- Women in STEM: Learn about women in STEM fields and how they got where they are now. (http://www.womeninscience.org/)

- American Astronomical Society (AAS), Astronomy Careers: Information about all the different types of astronomy careers and what students can do now to prepare for them (http://aas.org/education/careers.php)

Educator Resources

- Big Explosions and Strong Gravity: The BESG website contains information about the activities, the people behind the program, more helpful resources and contact information. (http://bigexplosions.gsfc.nasa.gov/)

- NASA for Educators: (http://www.nasa.gov/audience/foreducators/index.html)

- Afterschool Universe: Afterschool Universe is an afterschool astronomy program for middle schoolers covering the tools astronomers use, elements and spectroscopy, stars, galaxies, black holes and more. (http://universe.nasa.gov/au/)

- HEASARC (High Energy Astrophysics Science Archive Research Center): HEASARC is an archive for NASA missions relating to high energy phenomena, such as black holes, supernovae, etc, and contains educational resources. (http://heasarc.gsfc.nasa.gov/docs/outreach.html)

- Chandra Education Resources: The Chandra X-Ray Observatory website contains both formal and informal education resources. (http://chandra.harvard.edu/edu/index.html)

- Astronomical Society of the Pacific: Astronomy Society of the Pacific's website contains education resources, astronomy news and more. (http://www.astrosociety.org/index.html)

Big Explosions and Strong Gravity

A Day of Exploration into Supernovae and Black Holes

Saturday, April 26th, 2008

8:45 a.m. – 9:00 a.m.	Registration
9:00 a.m. – 9:30 a.m.	Greeting/Orientation (Universe Room)
9:30 a.m. – 10:25 a.m.	Group A: Rainbow Analysis (Galaxy Room) Group B: Rainbow Analysis (Nebula Room) Group C: Elements and You (Universe Room) Group D: Elements and You (Constellation Room)
10:30 a.m. – 11:25 a.m.	Group A: Elements and You (Universe Room) Group B: Elements and You (Constellation Room) Group C: Rainbow Analysis (Galaxy Room) Group D: Rainbow Analysis (Nebula Room)
11:30 a.m.	Black Hole activity (Universe Room)
12:15 p.m.	LUNCH + Astronomer Scavenger Hunt (Universe Room)
1:15 p.m. – 1:55 p.m.	Group A: Supernova Explosions (Galaxy Room) Group B: Supernova Explosions (Nebula Room) Group C: Black Holes in Orbit (Universe Room) Group D: Black Holes in Orbit (Constellation Room)
2:00 p.m. – 2:40 p.m.	Group A: Black Holes in Orbit (Universe Room) Group B: Black Holes in Orbit (Constellation Room) Group C: Supernova Explosions (Galaxy Room) Group D: Supernova Explosions (Nebula Room)
2:45 p.m. – 3:00 p.m.	Evaluations (Universe Room)

Scientist Scavenger Hunt

<u>RULES</u>:

1. Have fun! This is your chance to interview professional scientists and engineers.
2. Respect everyone's right to eat their lunch. There is no extra credit for finishing first.
3. Don't ask the same person more than one pair of questions.
4. Only ask people with the orange badges. They are your targets!
5. Try to keep the Q&A one-on-one rather than groups-on-one.
6. **Have the astronomer initial your answer after you write it down.**
7. Once you finish the list, go get your prize.

<u>QUESTIONS</u>:

Name: Initials: _______

1. Tell me about your best day or a typical day (you choose!) in your job.

2. Where were you born, or where did you grow up?

Name: Initials: _______

1. At what age did you decide you wanted to become a scientist/engineer and why?

2. What pets do you have, if any? If not, what might you want to have as a pet?

Name: Initials: _______

1. What did you do to prepare yourself for becoming a scientist/engineer (in high school, in college, etc)? What is/will be your highest degree?

2. What is your favorite season and why?

Name: Initials: _______

1. What kind of telescopes and/or other tools do you use in your work?

2. What is one of your hobbies that does not relate to the work you do?